University-National Oceanographic Laboratory System

Final Report of The Workshop on Scientific Shipboard Diving Safety

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Acknowledgments

To deal with the issues of research diving at sea, people representing a diverse spectrum of knowledge and skills needed to be assembled, challenged, and allowed to debate their way to a common point of view. It was critical from the perspective of ship operators, scientists, and Diving Safety Officers to provide for incorporation of new technologies and distant operations in an efficient and safe manner rather than to limit our present in situ activities at sea just to existing capabilities. This was not an easy task.

First, it took the vision, insight, and concerns of the late Captain John McMillan (NSF) to perceive the need to start the project, and the energy, experience, and personal involvement of Dolly Dieter (NSF), who took his place, to bring the project to a successful conclusion. NSF, along with NOAA, generously provided the resources to allow this process to take place.

I must thank the participants, Alice Alldredge, Timothy Askew, Jack Bash, David Casiles, E. R. Dolly Dieter, William Fife, Leon Greenbaum, Jr., Thomas Hall, Lynne Carter Hanson, John Harper, Michael Lang, Laurence Madin, Charles Mitchell, Jack Nichols, Robert Sand, Phillip Sharkey, Robert Steneck, James Stewart, Jon Witman, and James Williams for their constant and unerring commitment to our objectives despite frequent conflicting demands on their time. The participants showed their dedication by giving up holidays, weekends and evenings for long meetings and by responding to short lead times for preparing position papers. Their informality provided for creative interaction and lively discussions. My thanks to not only the individuals, but to the organizations which they represented and especially to the Undersea and Hyperbaric Medical Society, under whose auspices the workshop was conducted.

The workshop's planning committee members, Jack Bash, Lynne Carter Hanson, Robert Sand and Phil Sharkey deserve my thanks. I would especially like to thank Phil Sharkey for his dogged determination in pulling a coherent report out of our separate contributions.

Finally, I would like to thank, in advance, NSF and NOAA for their efforts toward bringing new technologies safely to the in situ scientific community. ◼

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Executive Summary

Chairman's Remarks

Research Diving at sea provides the scientist with a variety of unique capabilities.

- Direct observation of the behavior and interactions of individual organisms and their collection in near-surface (0 to 150 feet) open-ocean waters is possible. The organisms collected are frequently so delicate that other techniques, such as netting, are disruptive and destructive. Additionally, these organisms are frequently transparent and image poorly on even sophisticated cameras.

- Scientific diving teams are able to access, observe, quantify and collect near-surface benthic communities far from shore in a cost effective manner.

- Efficient, in-place servicing and securing of bottom and water-column data-gathering devices under open-ocean conditions can be performed.

Future implementation of these techniques is expected to increase and be extended, in state-of-the-art hyperbaric applications as well as through advances in the use of one-atmosphere in situ methods.

The marine operators and Masters of the academic fleet's vessels have expressed their desire for better role definition in assuring the safety of over-the-side, manned operations. Although scientists who dive and administrators of the research diving safety programs share the same concerns for safe diving procedures, they need assurance that implementation of safety regulations will not unduly impede scientific efficiency.

In order to address these issues, two workshops were funded by the National Science Foundation (NSF) and the National Oceanic and Atmospheric Administration (NOAA). The grant was administered by the Undersea and Hyperbaric Medical Society (UHMS). The first workshop was conducted by the UHMS and the second by the Graduate School of Oceanography (GSO) of the University of Rhode Island (URI). The workshops' objectives included establishing research diving-related guidelines for marine operators and Masters, and reviewing existing shipboard research diving safety documentation (especially that related to distant scientific programs). The workshop participants were tasked to look to the future as in situ technologies evolve for both hyperbaric and one-atmosphere applications.

> **Throughout the report there are sidebars which serve to define terms or set editorial notes off from the rest of the text.**

This report contains the results of the URI/GSO workshop. It is divided into three sections. The first supplies background by detailing the history of the issues, the mechanics of the workshop and perspectives of the attending constituencies; the second and third sections are composed of position papers prepared by session chairpersons which reflect the participants' consensus. The second section deals with specific, current issues while the third deals with the issues the participants see on the horizon. Summaries of the sessions' Findings and Recommendations start on the next page.

Findings and Recommendations:

Safety Issues

Authority and Responsibility

Findings

- The major participants during the execution of a diving operation are the vessel's Master (and crew), the Principal Investigator and the On-Board Diving Supervisor.
- The on-site individuals are backed up by a plethora of organizations (Research Vessel Operator's Committee: RVOC, University National Laboratory System: UNOLS, National Science Foundation: NSF, American Academy of Underwater Sciences: AAUS).
- The organizations' documentation (*UNOLS Shipboard Safety Standards, RVOC Safety Training Manual*, campus diving manuals, AAUS Standards) are internally consistent.
- A clearly defined requirement exists for a statement that will clarify the issues of responsibility and authority over scientific diving at sea.
- This workshop represents one of the first times each of the major parties appreciated the problems of the others.
- The process of defining authority and responsibility requires an integrated assembly of planning events, personnel briefings, and document sharing.
- While some responsibilities can be preassigned, others must be handled during the actual planning and execution process. ■

Recommendations

- Section 15 of the *UNOLS Shipboard Safety Standards* should be replaced with the version developed at the workshop (page 25).
- Direction of, and authority over, the execution of diving operations lies with the On-Board Diving Supervisor. ■

Multi-Institutional Cruises

Findings

- The process of preparing for a diving cruise involves a discrete number of invariable steps, interlaced with project specific requirements. The process includes: selection of the lead institution; documentation that all research diver certification requirements have been met; research diver review and approval process; and an initial letter from the lead institution's campus diving administration to the ship operator documenting the above.

- The process is brought to the ship at the beginning of the cruise in a full-scale meeting between the On-Board Diving Supervisor, the vessel's Master, and the Chief Scientist, together with appropriate others such as the Marine Superintendent (if available). ■

Recommendations

- A formal walk-through of the ship's equipment that the research divers will need (e.g., small boats, crane) with the Master, Chief Engineer, Diving Safety Officer, On-Board Diving Supervisor, Marine Superintendent and the Principal Investigator prior to a cruise is highly desirable.

- Through a procedure not dissimilar to that used for ALVIN proposals, the grant proposal, as written, should specify to the greatest extent possible details of the planned diving including the divers, the institutions, the ship (by class and preferably by name), the time, the location, the specialized and routine equipment required, the costs to be uniquely attributed to the diving operation, and an outline of an emergency plan. This could be assisted by requiring the attachment of a completed Pre-Cruise Dive Plan Form (page 29 of this report).

- Prior to the submission of the grant proposal, the Principal Investigator should work out with the desired ship operator and the respective campus diving administrations the details of the planned diving as outlined above.

- The description of the process described above and the Pre-cruise Dive Plan Form should be incorporated into appropriate NSF, UNOLS and RVOC documents.

- Uniformity across the fleet in the requirements placed on diving cruises is highly desirable. ■

Small Boats and Small Boat Operators

Findings

- Most vessel operators have small boat operation rules and regulations. However, when viewed from a fleet-wide perspective, these are not generally available, complete, or consistent with each other especially as they relate to at-sea diving support.

- A common standard should include operator requirements (training, certification, proficiencies, etc.), operational procedures (launch and recovery, diver assistance, support and communication, special diving conditions, etc.), dive planning involvement, a detailed checklist, and emergency procedures.

- The primary boat operator should normally be a member of the ship's crew. Science party operators must demonstrate, to the vessel Master's satisfaction, acceptable skills and knowledge. Having a boat operator with diving knowledge is useful to both the ship and the science party and should be encouraged. ■

Recommendations

- UNOLS/RVOC should develop a common set of guidelines for small boats and their operators, not unlike (in form) the standards AAUS developed for research diving. These guidelines should be incorporated, as appropriate, into the *UNOLS Shipboard Safety Standards*, the *RVOC Safety Training Manual* and other UNOLS/RVOC documents. These new guidelines should include coverage of the use of small boats for diving operations. Small boat topics that relate to diving should be incorporated into the documents mentioned above in both the small boat and diving sections.

- Small boats from which diving operations are conducted should, as a high priority consideration, always be equipped with a way of rapidly recalling the divers to the surface in an efficient manner. ■

Diver Evaluation and Training Standards

Findings

- Shipboard diving, when compared to near-shore diving conducted from small boats, requires additional diving skills and knowledge on the part of the scientific party as well as additional skills and knowledge on the part of the ships' crew. The assumption that all members of such expeditions have been adequately trained and indoctrinated in the tasks to be performed may not always be valid. It is imperative that all personnel involved in the diving operation have a clear understanding of the tasks to be performed, how they are to be accomplished and who the responsible individual is.

- The responsibility for the establishment of minimum standards for qualifying and training scientific divers, as well as running research diving safety programs, rests with AAUS. The implementation of those standards rests with the campus diving administrations. AAUS standards cover basic diver training but do not directly address day-to-day shipboard scientific diving operations.

- It is not uncommon for diving cruises to include diving personnel from institutions other than the vessel operator. It is sometimes difficult for foreign divers and divers from institutions which lack an AAUS model research diving safety program to demonstrate their qualification for research diving cruises. ■

Recommendations

- When a cruise is leaving from a port other than the home port, and there are research divers meeting the ship who are not yet qualified, inclusion of the Diving Safety Officer (or an authorized representative) in the scientific party as the On-Board Diving Supervisor is the preferable mode of operation. This approach permits the On-Board Diving Supervisor to conduct the required in-water checkouts of the divers and to qualify them on the spot. When this approach is used, research divers need to consider that they will not be permitted to dive if they do not meet the qualification criteria.

- The development of common policy approaches, evaluation criteria, and protocols for the testing of the proficiency of shipboard scientific divers and support personnel is needed. Consensual standards covering these items should be developed.

- All UNOLS members whose scientists carry out diving research or who operate a UNOLS research vessel should be Organizational Members of the AAUS so that they can fully participate in the development and evolution of research diving safety standards. ■

Emergency Planning

Findings

- Masters and mates are prepared to respond to life-threatening events at sea on an ad hoc basis.

- Diving cruises require specific plans to deal with medical advisory communication, evacuation, and location of operational hyperbaric chambers that have medical support.

- Available chamber location information receives little distribution even though it is useful in operational area planning. ■

Recommendations

- The On-Board Diving Supervisor should be given primary responsibility for the assembly of the information and protocols that go into the Pre-cruise Dive Plan.

- If an accident occurs, the Master of the main vessel has the responsibility for establishing communication with pre-defined medical advisory personnel. Both the scientific party and the ship's crew should understand how to communicate with the agencies involved in medical emergency and rescue.

- Research divers (working with the vessel EMT when present) should be prepared to deal with oxygen administration and emergency management.

- Emergency drills should be held on vessels conducting diving operations.

- With the appropriate approval of UNOLS, an emergency planning file should be established at the UNOLS office. The file would contain past emergency plans including information on medical and evacuation support, recompression facilities, response chart documenting 'response-radius' of the evacuation facilities and other emergency contacts. An on-line computer data base that keeps track of the plans in the file should be an integral part of this project.

- As part of a diving cruise emergency plan, the On-Board Diving Supervisor must include details concerning: contacting medical advisory groups; evacuation procedures; diving operations; and emergency chain of command, including 'first-responder aid' communication. A 'response-radius' chart should also be prepared. A copy of all emergency plan documentation should be sent to the UNOLS office for inclusion in the Emergency Plan file.

- General cruise emergency planning would benefit from documentation in existing UNOLS and RVOC marine safety publications. ■

Recompression Chambers

Findings

- A review of the history of academic research diving does not justify the requirement of on-board recompression chambers.
- Chambers may be desirable for diving techniques/equipment that are outside of the current practices of the scientific diving community.
- Of the chambers available, a double lock multi-place unit is the superior choice.

Recommendations

- Normal at-sea scientific diving from UNOLS vessels does not require the provision or use of an on-board recompression chamber.
- Diving beyond the experienced norm, especially in a remote site, should be reviewed on a case-by-case basis as part of the dive planning process to determine if a chamber is warranted.
- The general level of emergency medical preparedness should be enhanced by encouraging the training of crew members (and even interested research divers as Emergency Medical Technicians).
- In-water, oxygen decompression or the use of NITROX should be evaluated as techniques capable of providing greater safety margins.

Findings and Recommendations:

Looking Ahead

New Technologies

Findings

- Relatively new technologies such as hyperbaric use of NITROX, HELIOX, new diving tables, diving computers, and multiple tethered diving have now entered the academic diving community. Additionally, both manned submersibles (including One Man Atmospheric Diving Systems: OMADS) and unmanned (Remote Operated Vehicles: ROV, and Autonomous Underwater Vehicles: AUV) technologies are extending our subsea horizons.

- Regulatory mechanisms appropriate for hyperbaric exposure exist, but while satisfactory for classical diving techniques, they must now address emergent innovations.

- Issues to be dealt with include availability of access to vehicles and resources, handling technical complexities, and training of scientist participants. ■

Recommendations

- UNOLS should establish a standing committee (i.e., the *In-Situ Science Committee*: ISSC), composed of competent, interested, and involved parties including vessel operators, academic and commercial submersible operators, scientists, Diving Safety Officers, organizational representatives (e.g., UNOLS/RVOC, AAUS) and representatives from interested Federal agencies (e.g., NSF, NOAA, ONR, Department of the Interior, Department of Energy). The committee should deal with issues such as the establishment of standards for operating, contracting, safety and insurance, coordinating and scheduling, and shared use as well as provide advice to agencies. This recommendation (establishment of the ISSC) is similar to one of the UNOLS Submersible Science Study's (S^3) recommendations.

  The ISSC is visualized as occupying a position comparable to the Research Vessel Operators Committee (RVOC) and the Fleet Improvement Committee (FIC) and should encompass the current ALVIN Review Committee (ARC) in addition to newly established interest groups dealing with submersibles (other than ALVIN), OMADS, ROVs, and AUVs. Two mechanisms that could be employed in the structuring of this committee (apart from the ARC component) are: (1) appoint a large ISSC whose members are divided into functional groups to address identified problems; or (2) create a smaller standing ISSC which would convene ad hoc panels of outside experts to deal with specific issues. ■

Future Needs and Projects

Findings

- Since 1977 the AAUS has been the national body representing the U.S. Scientific Diving Community. However, no formal links exist between AAUS and UNOLS/RVOC despite commonality of interest and congruity of membership.

- AAUS has the expertise to provide services to UNOLS/RVOC in the area of diving information, standards, statistics, reciprocity, expert assistance and representation as well as a forum for resolving research diving issues. ■

Recommendations

- UNOLS/RVOC should utilize the AAUS to provide consultation and advice on research diving issues. In support of this utilization UNOLS/RVOC and AAUS should establish formal and consistent links to assure such benefits as cross-representation at significant meetings, cross-reporting in newsletters and, most importantly, cross-convening of joint issue topical conferences such as this workshop.

- As a way of supplying technical links and in consonance with the report of the S^3, the Diving Safety Officers of the UNOLS institutions should form a sub-committee under the proposed In situ Science Sub-Committee (ISSC).

- The AAUS Board of Directors should establish a committee within the AAUS composed of the UNOLS Diving Officers.

- UNOLS and its member institutions should pursue, through the AAUS, an agreement with NOAA concerning the reciprocal recognition of each other's research diver credentials.

- The peer review of science proposals involving research diving should include the best available (e.g., a Diving Officer from a UNOLS institution) review of diving operational safety and feasibility considerations.

- Statistics should be kept by UNOLS concerning diving from vessels in the academic fleet. Copies of institutional diving logs from all cruises should be provided by the Chief Scientist as part of the normal Post-Cruise Report to UNOLS.

- The diving-related portion of the UNOLS research vessel inspections should be enhanced. This review should concentrate on the diving equipment and the ship equipment (i.e., small boats and motors) as well as procedures for use and access to accident-response equipment.

- All UNOLS member institutions who either conduct scientific diving or whose ships are used for research diving cruises should be Organizational Members of the AAUS.

- Methodologies should be developed for divers whose institutions do not have formal scientific diving programs in order that they may fulfill certification requirements when they need to participate in UNOLS cruises.

Section One:

Introduction, Overview and Perspectives

Introduction

Background

To understand the issues underlying the current concerns regarding scientific diving at sea, one must go back in time to the late seventies. On 5 November 1976 Federal OSHA first issued standards[1] regulating commercial diving in which they defined commercial diving as 'any diving in which an employee/employer relationship existed.' Under these rules, OSHA classified diving researchers as commercial divers thereby putting significant operational and safety constraints on diving by the scientific community. Among the problems with the OSHA regulations that were cited by members of the scientific diving community were a number of specified changes in operating methods which the scientific diving community considered unsafe[2]. Additionally, these changes would have caused a substantial reduction in useful science time and vessel space at sea by reducing operational efficiency.

In exempting the scientific diving community OSHA determined that, '. . . there are significant differences between commercial diving and scientific diving . . .', and amended its rules to exempt scientific diving that is '. . . under the direction and control of a diving program utilizing a diving safety manual and a diving control board meeting certain specified criteria.'

OSHA's amendment to Subpart T was finalized when the 7th Circuit of the U.S. Court of Appeals denied the petition of The United Brotherhood of Carpenters and Joiners on the grounds that the union lacked standing to bring the suit. This was the first time in history that a court had denied a labor union standing in such a case.

The scientific community strongly disagreed with the OSHA action, feeling that the scientific community had established and maintained an excellent safety record as a self-regulated entity. In order to respond to this perceived threat, the American Association of Underwater Sciences (AAUS) was formed. The group effectively presented the scientific community's diving safety record, as well as its needs and requirements. After protracted hearings and reversals, OSHA finally exempted the research diving community on 26 November 1982. OSHA's ruling withstood a subsequent court challenge.

The University National Oceanographic Laboratory System (UNOLS) adopted the AAUS standards in 1985 for all shipboard diving undertaken at member institutions. In 1988 the National Science Foundation (NSF), a major supporter of both UNOLS and the academic institutions within the organization, expressed concern about the application of these safety standards and their relation to research-related accidents that had taken place within the scientific community. Some of the accidents occurred within the marine field, both at sea and ashore, and included two shipboard diving non-fatalities and one remote site diving fatality. Because

UNOLS is an association of institutions. Each member institution uses, or operates and uses, sea-going facilities and maintains an academic program in marine science. UNOLS' objective is to coordinate and review the utilization of facilities of academic oceanographic research, access to these facilities, and the current match of facilities to the needs of academic oceanographic programs. UNOLS makes appropriate recommendations of priorities for replacing, modifying or improving the numbers and mix of facilities for the community of users.

[1] 41 Federal Register 48950

[2] 'Federal Regulation of Scientific Divers,' Sharkey, P. and Austin, L.: 1983, in Oceans '83 Proceedings, Marine Technology Society, Washington, D.C.

of this, and especially because of concerns expressed by UNOLS ship operators, NSF decided that there was a need to precipitate useful discussions among the parties involved in scientific diving operations. The ship operators felt uneasy with over-the-side diving operations, especially in the open ocean, the diving scientists felt somewhat put upon by the rules, regulations and complications of meeting the diving regulatory requirements, and the campus diving administrations found themselves in the middle of these issues. ■

The UHMS Workshop on Safety Guidelines for Diving from Ships at Sea

Throughout the report the term 'campus' is used generically and refers to a local administrative unit that something is part of. 'Campus diving administration' is also used as a general term, to accommodate the differences in the assignment of authority at different institutions. At some institutions the actions assigned to the campus diving administration may require only the work of a single individual while at others it may require a committee or board meeting.

A workshop to discuss the diving-related issues was conducted on Friday, 29 April 1988, by the Undersea & Hyperbaric Medical Society (UHMS) under NSF/NOAA sponsorship. Its goals were defined as: establishment of guidelines for the oceanographic vessel Masters; review and assessment of control of research diving operational safety; the development of an annotated bibliography dealing with scientific diving at sea, its problems and issues (i.e., physiology, training, experience, etc.); and publishing the results of the deliberations. UHMS is in the process of completing the output from this initial workshop[3].

The workshop convened three primary groups: commercial divers, Navy divers, and scientific diving administrators. A review of the transcripts from the workshop showed that while each of the parties had good and sufficient reasons as to why they conduct diving operations as they do, each party had differing missions, philosophies, strategies, and resources. As a result, no substantial beneficial interaction occurred. The discussion did not include a definition of responsibility for, and authority over diving operations, which led to the conclusion that further efforts were required to address the needs and interests of the scientific community. A vigorous debate regarding chamber use also appeared to warrant additional discussion. ■

The RVOC is a committee of UNOLS. Its purpose is to promote cooperation among the marine science research and educational institutions and to represent their interests in the areas of marine operations, government regulations, labor relations, and public relations as those areas effect their research fleets. Membership in the RVOC, while based on representation from UNOLS operator institutions, is also open to non-UNOLS institutions who operate research vessels for purposes similar to UNOLS.

The URI/GSO Workshop on Shipboard Scientific Diving Safety

Subsequent to the UHMS workshop, the need to bring together a broader and different group of people to continue the process of establishing safety guidelines and standards for research diving was reinforced by a number of events. A major effort had gone into revision of the *UNOLS Shipboard Safety Standards*[4] (which included a section covering research diving); the *Research Vessel Operators' Committee* (RVOC) *Safety*

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[3] 'Safety Guidelines for Diving from Ships at Sea,' Greenbaum, L. (Editor): Draft, Undersea and Hyperbaric Medical Society, Bethesda, MD.

[4] 'UNOLS Shipboard Safety Standards,' 1989: University National Oceanographic Laboratory System, University of Washington, Seattle, WA.

Training Manual[5] was in development (which also included a chapter on research diving); and the *UNOLS Submersible Science Study* (S^3) was in progress.

Other new information that needed examination came from the AAUS, which had just put forth new medical examination schedules and published material that had not been considered at the UHMS workshop, concerning cold water diving, diving computers, and safe rates of ascent. Additionally, 58 campus diving administration representatives (Diving Safety Officers and Diving Control Board members) from 41 institutions met at Woods Hole Oceanographic Institution, as part of the AAUS Annual Symposium, and documented their concerns[6] relative to topics of safety, equipment, procedures, training, new diving technologies and reciprocity.

The first S^3 Committee compiled a report in 1982 which was primarily concerned with the ALVIN upgrade. The present S^3 was charged by UNOLS to draft a plan for conducting a study of the broad scientific program requirements for submersibles and related technologies in the next decade and beyond.

The study was focused on two principal objectives:

- **To assess the trends, patterns, and directions for academically-based ocean science research programs that can best be served by submersible systems, both manned and unmanned. This assessment was to cover the full range of depth requirements needed by science.**
- **To develop a comprehensive submersible science facilities plan which satisfies the science requirements identified above, including the rationale for such facilities, and possible funding and management arrangements.**

Specific tasks for the URI/GSO workshop included:

1) Study of the new information available on remote site and shipboard diving safety and effectiveness;

2) Utilization of new information in a detailed review of diving section of the *UNOLS Shipboard Safety Standards* and the *RVOC Safety Training Manual;*

3) Review of the consensual research diving safety standards of which the AAUS is custodian and which serves as the backbone of the diving section of the current *UNOLS Shipboard Safety Standards*; and

4) Examination of the need for a potential extension of the UNOLS standards to specifically address the concerns raised by the operators of academic research vessels and the needs resulting from research diving conducted at remote sites.

The planning for the URI/GSO workshop differed somewhat from that for the UHMS workshop. The primary goal was to bring together experts from inside UNOLS and scientific diving community to review both the output from the UHMS workshop and the new material that was available. This review was targeted at providing the greatest possible assistance to UNOLS in the establishment of research diving safety guidelines and standards that were efficient with respect to scientific resources.

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[5] 'Research Vessel Operators' Committee Safety Training Manual,' Bash, J. (Chairman): In Press, University National Oceanographic Laboratory System, University of Washington, Seattle, WA.

[6] 'Minutes of the Annual Research Diving Safety Officers Meeting: 1989', Sharkey, P. (Chairman): 1989, American Academy of Underwater Sciences, Costa Mesa, CA.

A clear part of assuring diving scientists' safety was meeting the goal of improving communication between organizations and the members of the on-site teams involved with the diving. General concepts and specifics concerning the assignment of responsibility and authority for shipboard diving is unclear and contradictory especially when one asks the on-board participants who is in charge of what. This is of special concern to ship Masters at sea. Documentation dealing with the qualification and interchange of research divers among institutions is poorly defined as is the transmission, updating, and storage of that documentation. ■

Phase One

The URI/GSO workshop began with an examination of the structure of the scientific diving community. Figure 1 shows the interrelationships defined by that examination. The federal agencies (NSF, the Office of Naval Research (ONR) and others) are coupled together through the mechanism of UNOLS to deal with academic fleet operations. UNOLS includes not only all of the academic vessel operators (who make up the membership of the RVOC) but also other institutions who conduct major scientific research activities at sea. This strongly linked system is driven by science needs. Science, through peer review, determines funding of research and this involvement of the working scientist in both UNOLS and AAUS activities creates a strong, but informal, link. Additionally, AAUS is highly responsive to campus diving administrations. However, as Figure 1 shows, there is no direct linkage between the AAUS and the ship operators. Therefore, one of the purposes of this second workshop was to determine if a link was important and, if it was, to find an effective means to establish and maintain it.

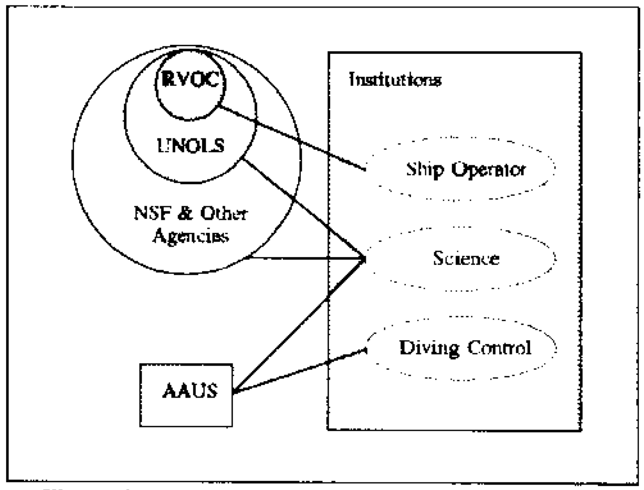

Figure 1: Links in the Scientific Diving Community.

Although there are no formal links between the organizations, there is commonality in membership. The Marine Technology Society (MTS) estimates that there are 350 marine research institutions in the nation. Fifty-six of these are members of UNOLS (Figure 2). An examination of AAUS membership within UNOLS shows that all but eight UNOLS institutions have AAUS Individual Members on campus, 16 of the UNOLS institutions are AAUS Organizational Members, and seven are in the process of joining (Table 1). Of the 56 UNOLS institutions, 21 are members of the RVOC. Eleven RVOC institutions are AAUS Organizational Members, four RVOC institutions are in the process of becoming AAUS Organizational Members, and all of the RVOC members have Individual Members of AAUS on campus. Despite this high degree of organizational correspondence, no formal mechanism exists for making use of these interrelationships.

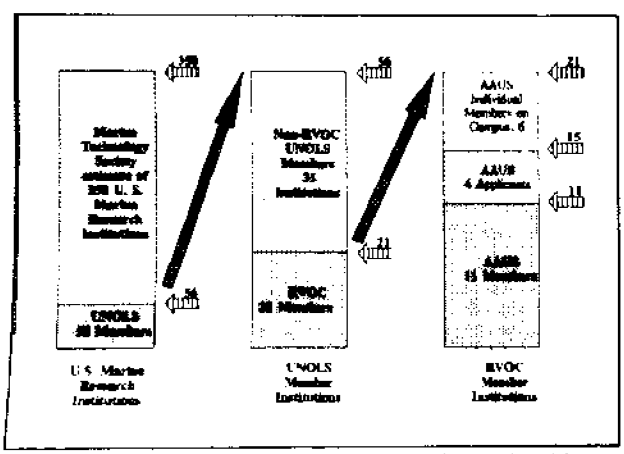

Figure 2: UNOLS, RVOC and AAUS membership

Communication between organizations is not the only issue. In addition, there are issues concerned with responsibility and authority, liability and qualifications, safety and accident management, scientific efficiency, documentation, new technology and practices, and continuity. An overriding objective in dealing with these problems is to avoid setting up excess bureaucracy that would inhibit the accomplishment of primary tasks. To address these concerns, communication can and must be improved. Better communication is required between the organizations, between the individuals at the dive site, and between the organizations and the on-site individuals.

OMADS, or One Man Atmospheric Diving Systems, are small, light, scientist-piloted submersibles. They range from simple human powered systems such as armored diving suits like the *JIM* and *NEWT Suit* to small, light, one-person submersible systems such as *Deep Rover*.

There are new technologies that will require the science community to deal with operational safety issues similar to those raised by research diving at sea. An example is the use of non-dedicated vessels with OMADS. Although one workshop is unlikely to resolve all these issues, it was hoped that, by providing a forum for knowledgeable people to respond with individual points of view, either agreement on the various issues, or equally important, documentation of disagreement would be produced so that the community could develop solutions to its problems.

Figure 3 compares the approach taken in the UHMS workshop with that of the URI/GSO workshop. The UHMS brought together groups of divergent viewpoints, practices and concerns about diving safety. URI/GSO brought together the groups with specific concerns with, and influence over, scientific diving (ship operators, scientists, and campus diving administrations) together with representatives of AAUS and UHMS. Each of these three constituencies brought various organizational affiliations which typically were: ship operators (UNOLS and RVOC), scientists (UNOLS and AAUS) and campus diving administrations (AAUS).

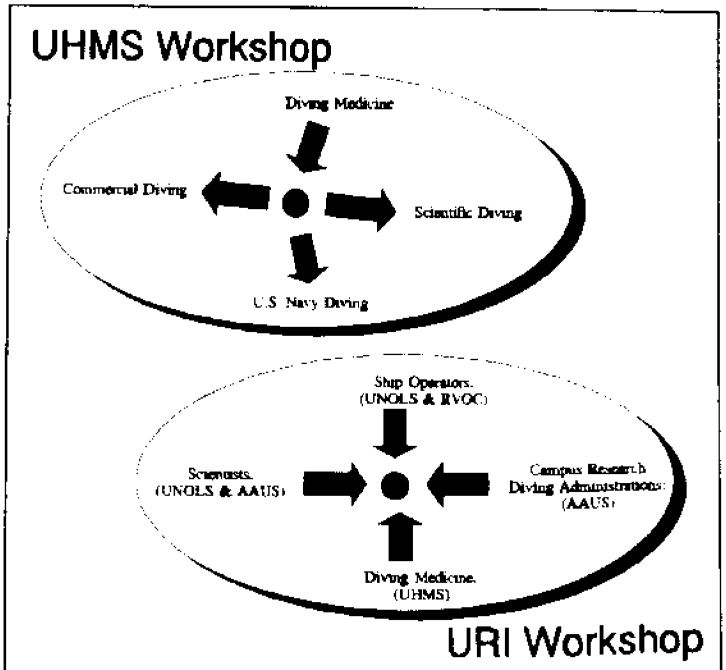

Figure 3: Participating constituencies in the UHMS and URI/GSO Workshops.

Copies of existing documentation were provided to the workshop participants (i.e., *UNOLS Shipboard Safety Standards*: Section 15 - Diving; *RVOC Safety Training Manual*: Diving Section; and *AAUS Standards for Scientific Diving Certification and Operation of Scientific Diving Programs*).

The charge to the panel was to produce:

1) A statement, addressing the special problems of multi-institution cruises, which outlines the responsibility and authority of: the diving scientist, the research vessel operator, the research vessel Master, and the campus diving administration;

2) A review of the diving section in the *UNOLS Shipboard Safety Standards* and the *RVOC Safety Training Manual*, with recommendations for changes as needed;
3) Recommendations to UNOLS/RVOC covering special equipment and procedures requirements for diving from UNOLS vessels (i.e., small boats, medical equipment, decompression tables and procedures, and recompression chambers);
4) Recommendations to UNOLS/RVOC concerning requirements for special personnel when diving is conducted from UNOLS vessels;
5) Detailed checklists for diving cruise and remote site planning including casualty evacuation;
6) Recommendations to UNOLS/RVOC for standards defining the minimum diving skill and knowledge required of diving researchers who work from UNOLS vessels or at remote sites; and
7) Recommendations for linking the diving scientists, the marine operators and the Diving Safety Officers together in a manner that will improve the effectiveness of the above items. ■

Institution Name	AAUS Org. Member	AAUS Indv. Members.
Alabama Marine Env. Sci. Consort.		Yes
Univ. of Alaska		Yes
Bermuda Biological Station	App.	Yes
Bigelow Lab. for Ocean Sci.		
Brookhaven National Lab.		
Univ. of Cal, San Diego - SIO	Yes	Yes
Univ. of Cal, Santa Barbara		Yes
Cape Fear Technical Inst		Yes
Columbia Univ. - LDGO		Yes
Univ. of Connecticut	RA	Yes
Univ. of Delaware		Yes
Duke Univ/Univ. of North Carolina Consort	Yes	Yes
Florida Inst. for Ocg		Yes
Florida Inst. of Technology		Yes
Florida State Univ	Yes	Yes
Harbor Branch Oceanographic Inst	Yes	Yes
Harvard Univ		Yes
Univ. of Hawaii	Yes	Yes
Hobart & William Smith Colleges		
Johns Hopkins Univ.		Yes
Lehigh Univ.		
Louisiana Univ. Marine Consort.	Yes	Yes
Univ. of Maine	App	Yes
Marine Sci. Consort.		Yes
Univ. of Maryland		Yes
Massachusetts Inst. of Tech		Yes
Univ. of Miami - RSMAS	Yes	Yes
Univ. of Michigan		Yes
Monterey Bay Aqua. Research Inst	Yes	Yes
Moss Landing Marine Lab.	Yes	Yes
Naval Postgraduate School		
Univ. of New Hampshire		Yes
New York State Univ.-Buffalo		Yes
New York State Univ.-Stony Brook		Yes
North Carolina State Univ.		Yes
Univ. of North Carolina-Wilmington	Yes	Yes
Nova Univ		Yes
Occidental College		Yes
Old Dominion College		Yes
Oregon State Univ	App	Yes
Univ. of Puerto Rico		Yes
Univ. of Rhode Island - GSO	Yes	Yes
San Diego State Univ.	Yes[1]	Yes
Sea Education Association		Yes
Univ. of South Carolina		Yes
Univ. of South Florida	RA	Yes
Univ. System of Ga., Skidaway Inst. of Ocg.		Yes
Univ. of Southern California	App	Yes
Univ. of Texas	App	Yes
Texas A & M Univ.	Yes[2]	Yes
Virginia Inst. of Marine Sci	Yes	Yes
Univ. of Washington	Yes	Yes
Univ. of Wisconsin- Madison		
Univ. of Wisconsin-Milwaukee		
Univ. of Wisconsin-Superior		
Woods Hole Ocg. Inst	Yes	Yes

RVOC Institutions are underlined.
App=Application under review.
RA=Requested application.

[1] Several California State University campuses share an AAUS membership.
[2] The main TAMU campus is not a member of AAUS, the marine lab is.

Table 1: UNOLS Members showing RVOC and AAUS Affiliations.

Phase Two

Once the workshop participants were identified, they were supplied with the documents of interest and met in Washington D.C. from 18-20 February, 1990 for two and a half days. Resulting documents were prepared, exchanged and edited, and then a small working group convened at the W. Alton Jones Campus of the University of Rhode Island on 2-3 July 1990 for a day and a half to provide editorial assistance with the final report and complete work on some unresolved issues. The following is the report from the Washington D.C. and W. Alton Jones meetings. ■

The URI/GSO Workshop on Shipboard Scientific Diving Safety, an Overview

The URI/GSO Workshop on Shipboard Scientific Diving Safety, held in Washington, DC from Sunday through Tuesday, 18-20 February 1990, consisted of eight major elements (Appendix A on page 61: Schedule of the URI/GSO Workshop on Shipboard Scientific Diving Safety). The 21 participants (Appendix B on page 64: List of Attendees) represented various academic institutions, national oceanographic laboratories and other involved organizations including: American Academy of Underwater Sciences, Harbor Branch Oceanographic Institution, Marine Biological Consultants Applied Environmental Sciences Inc., Northeastern University's Marine Science Center, Research Vessel Operators' Committee, Smithsonian Institution, Texas A & M University, University of Rhode Island's Graduate School of Oceanography, University of California at San Diego's Scripps Institution of Oceanography, University of Miami's Rosenstiel School of Marine and Atmospheric Sciences, University of Maine's Darling Marine Center, University National Oceanographic Laboratory System and Woods Hole Oceanographic Institution. Although the Director of the NOAA/NURC (National Oceanic and Atmospheric Administration/National Undersea Research Center) program was unable to attend the URI/GSO workshop, NOAA was a co-sponsor. The attendees were selected to assure representation from science, ship, and diving administration constituencies. Each constituency was asked to state its perceptions of shipboard scientific diving safety and expectations for the workshop.

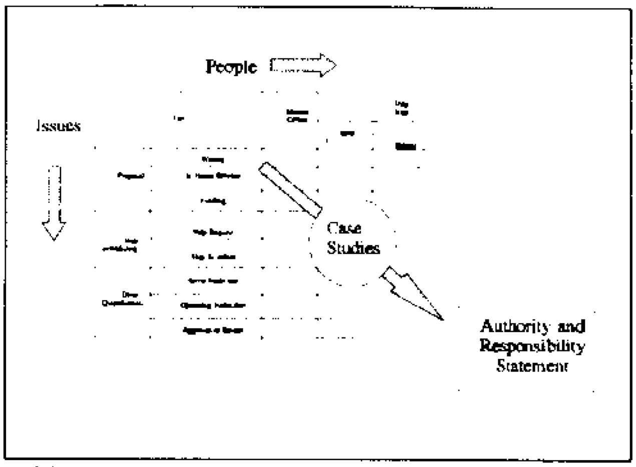

Figure 4: Use of the Matrix to develop a statement of Responsibility and Authority by examining case studies.

Following a slide presentation illustrating blue water diving techniques, a session was held to present a short example of the application of a matrix (Appendix C on page 66: The Matrix) to a case study. This matrix was then used for detailed examination and review by three task groups (Figure 4).

Each task group was carefully designed to include members from each constituency. One task group was chaired by a representative of each constituency. The task groups were asked to perform three assignments:

1) Review each cruise event, determine which listed individuals and organizations were involved in that event (adding any overlooked participants) and rank the participants' involvement with respect to their own subjective appreciation of the participants' level of combined authority and responsibility.

2) Conduct a detailed examination and review of several case studies to determine that their rankings were appropriate.

3) Apply the task group's matrix results to case studies.

Formal presentations and discussions were held on the following topics: multi-institutional diving cruises, special personnel for diving cruises, responsibility statements, diver training standards, small boats and small boat operators, emergency planning and accident management, recompression chambers, new technologies issues, and future needs. The closing sessions defined requirements to complete the current tasks.

MAS is a private contractor to UNOLS (and others). It supplies medical advice to ships at sea.

The participants were asked to make recommendations to NSF concerning the safety of scientists diving at sea. The workshop also developed a few examples of recommended procedures, such as the Pre-Cruise Dive Plan form, for use by organizations concerned with the process of scientific diving from academic research vessels at sea (e.g., NSF, UNOLS, RVOC, NOAA, AAUS). It is hoped that these organizations and others such as the Medical Advisory System will, through their normal processes, make the best possible use of this information. **I**

Perspectives on the Problem

The first formal session of the workshop was designed to give the participants the opportunity to present their organization's shipboard diving concerns, their perceptions of the issues and to state their views on required workshop output. The format used was to have a representative of each constituency make a presentation, followed by discussion among the attendees. ■

UNOLS/RVOC - Jim Williams

In 1986 the revised *UNOLS Shipboard Safety Standards*, which for the first time included a diving section, was published. The standards are updated periodically, most recently in 1989. The RVOC makes the point that these safety standards are to be considered as minimum guidelines for UNOLS research vessels. All UNOLS ship operators and users of UNOLS vessels are expected to be thoroughly familiar with these standards and comply with their recommendations. More detailed or stringent requirements, if necessary, are included in institutional policy documents and even state law.

The crucial test for a set of standards is the critical experience that one goes through in an investigation following an accident. Did the standards answer the hard questions that are asked such as: 'who is in charge of safety? How much training has been done? Have regulations been posted? Have inspections been held?' Pressure to provide increased protection for all employees has produced substantial changes in shipboard policy documents.

Discussion

All activities have recognized hazards and going to sea has its own. The scientific community, in concert with academic institutions, the sponsors of science programs, and UNOLS, has worked hard to do everything possible to provide a safe working environment. This consensual effort has been highly effective and has resulted in the establishment of a clear standard of practice for the U.S. research fleet, the *UNOLS Shipboard Safety Standards.* These standards reference the *American Academy of Underwater Sciences Standards for Scientific Diving Certification and Operation of Scientific Diving Programs* as the accepted standard of practice of the UNOLS research diving community.

Comparing the academic community to others, it is clear that the academic community does not document either general shipboard or diving activities to the extent that, for example, the U.S. Navy does, with its extensive manpower availability and special needs. However, the academic community does claim to document in more depth than commercial operators. The most significant difference in concept between academic and commercial diving is that the primary responsibility for safety rests with the individual research diver. This approach is quite unlike the military or commercial system in which primary responsibility rests with the line supervisor. Additionally, institutions interact as equals in a collegial relationship. One does not 'boss' the other, and this underlines the principle of local control.

One of the workshop objectives was to determine if available policy documentation (e.g., the UNOLS standards, AAUS manual, etc.) are sufficiently detailed to reflect shipboard needs, including definition of items such as the Master's responsibility. An energetic debate between shipboard operators and divers swirled around the issue of degrees of specificity desirable for written procedures. The participants from the research vessel community took the position that more specific definition of responsibility and authority is desirable. The research diving community felt it was best to establish minimum standards in no greater detail than was absolutely necessary, details being best established on the local level as the situation demands.

It was pointed out that the divers need to keep up with advances in equipment, such as: buoyancy compensators, NITROX, dry suits and diving computers. AAUS felt that they fulfill this role by holding workshops and disseminating information on new technology to the campus diving administrations (Appendix D on page 72: AAUS Bibliography for details of various workshop proceedings). In addition to establishing standards, AAUS stated that they also accumulate statistics relative to shipboard diving experiences and accidents in the form of a database.

NITROX is a 'man-made' breathing mixture composed of nitrogen and oxygen. These gases are in a rough ratio of four to one in regular air. By producing a mixture that has a higher proportion of oxygen, it is possible to lessen the narcotic effect of breathing nitrogen under pressure and to reduce the amount of nitrogen absorbed by the diver which limits the time a diver can stay underwater safely. Some amount of nitrogen must be present since oxygen becomes toxic when breathed at a partial pressure of two atmospheres or more. HELIOX (an expensive mixture of Helium and Oxygen) is used for very deep diving where oxygen toxicity, the narcotizing effect of nitrogen and the density of the breathing gas are limiting factors.

The point was made that, regardless of the specificity of the standards, external control of the diver ceases when the diver drops over the side. At that point the individuals must be operationally responsible for their own safety. It became clear from the discussion, however, that in order to keep the standards generic, the ship's Master requires a clear responsibility/authority document. He is held, by both the institution and the U.S. Coast Guard, to be responsible for the ship and the people on board even when they are over the side and even though it is clear that he has no actual control over a diver in the water.

It was further suggested that the concept of having an On-Board Diving Supervisor specifically identified from among the research party whose primary responsibility is the safety of the operation is desirable. However, it is frequently impractical due to cost and space limitations to have someone on board uniquely for that role. The point was made that personnel controlling the diving operation must have the confidence of the ship's Master and have a relationship similar to that of the Master and the Chief Engineer. ■

RVOC Safety Training Manual Subcommittee - Jack Bash

The creation of the *RVOC Safety Training Manual* grew out of a realization within the RVOC that commonality in training and further definition of the shipboard operators' role was required. The concept was underlined by the results of fleet inspection teams that review the research vessels every two years. A committee was set up through the RVOC (with UNOLS endorsement) to draft a specific training manual, now in preparation with publication expected during the summer of 1990. In contrast, the *UNOLS Shipboard Safety Standards* is a policy document that provides RVOC members with minimum guidelines for research vessel safety. Section 15 of these standards covers diving safety.

The Safety Training Manual is written for a seaman, under the presumption that he or she has not read other manuals. The first chapter of the manual (there are 14 chapters) is designed to be used as a summary orientation document for the scientist. In a sense, it will be two manuals in one: training for the crew, and orientation for the scientist. The definition of its approach, contents, and downstream usage is expected to be subject to continual redefinition. Training procedures, and training video tapes, may come out of this manual. The RVOC can consider minor changes prior to the publication date. The manual is a living document, designed to accommodate changes in technology and be revised periodically.

Discussion

Questions were raised about the necessity of technical changes in the document to reflect current diving practice. For instance, the Trendelenburg position (a left-side-down, head low transport position) featured in the present document, has been shown recently not to be helpful.

The average non-diving crew members focus on the danger of an equipment failure resulting in running out of air. This is not a problem that occurs with any frequency. In any case, the crews' concern should be focused on the organization and control of the emergency aspects of the operation, not on a diver's potential individual problem.

The *RVOC Safety Training Manual* contains more specific details on diving techniques than are included in the AAUS manual. This is because AAUS standards and guidelines are at the policy level (as are the UNOLS Safety Standards) while the *RVOC Safety Training Manual* is more specific and should be viewed at the same level as AAUS technique documents. The definition of terms should be constant within all of the documentation. Ideally, there should be no discrepancy between guidelines and training.

It was critical to define, with specificity, the role of the lead institution's Chief Scientist and the Principal Investigator of the diving program in order to allow a clear decision regarding which person or organization is responsible. For example, the lead institution's campus diving administration is not always a part of the Principal Investigator's home institution.

The comment was made that there are significant differences between the operations of coastal benthic divers and open-ocean divers. Concern was expressed that both the *UNOLS Shipboard Safety Standards* and the *RVOC Safety Training Manual*, as they exist, do not fairly represent benthic-oriented diving from relatively large ships offshore, where the divers work with both comparatively heavy research equipment and samples. The operational differences become less distinct as ships get closer to shore and smaller.

It was also felt that the *RVOC Safety Training Manual* does not deal with equipment support diving in which untethered scuba diving takes place in connection with OMADS and tethered vehicles such as the Remote Underwater Manipulator (RUM). A plea was made for a formal review mechanism to be established involving the concerned parties. This mechanism would not be unlike the treatment given the radiological section of the UNOLS' *Standards* (i.e., have the document reviewed by the diving community through AAUS).

The RUM is a unique vehicle designed to be controlled through a cable connection to the surface. It crawls along the bottom and features deep water capability, an advanced manipulator and a high quality video system. It can carry scientific experiments. Divers are used to help launch and recover it in the open ocean.

The participants clearly felt that more mission-specific details should be developed as part of an on-board cruise dive plan. A vigorous discussion on the subject of degrees of specificity took place. The final outcome favored the inclusion of details. The identifying of exact marine band communications rather than simply saying 'radio' was cited as an example. Additionally, questions dealing with the configuration of the vessel and its abilities need to be addressed. Will there be open-ocean diving? Live boating? Will the boat be underway? In the case of saturation diving habitats and shore-based operations, ships are not considered to be the controlling element.

It was considered critical to specify more interaction among the small boat crew, the primary vessel, and the research divers under both normal and emergency conditions. This is especially important in situations such as in the Antarctic where, for instance, outboard motors must be kept running or they freeze even though diver safety considerations would suggest shutting them down.

The discussion then shifted to the responsibility of the small boat operators and the vessel from which the actual diving takes place. Should the operator be primarily a competent seaman or a research diver? The tenor of opinion was that competent seamanship is more important but diving knowledge could be advantageous, especially in the case of accidents and the early recognition of problems such as an injured or lost diver. In large-scale operations, a dive-ready, back-up diver should be in the boat, but it was not recommended that the boat tender leave his vessel to interact with the in-water operations. It was felt that the On-Board Diving Supervisor should generally remain on the large vessel observing the operation, linked to the communication system and in a position to take charge in emergency situations. It was stated that activities in which the most dangerous conditions occurred was loading and off-loading of personnel between the main vessel and the smaller dive boat.

If an accident occurs, the Master of the main vessel has the responsibility for establishing communication with pre-defined medical advisory personnel. The diving people working with the vessel EMT(s) should be prepared to deal with oxygen administration and emergency management. The idea of having emergency drills on board a vessel conducting diving operations was put forward. Both the scientific party and the ship's crew must clearly understand how to communicate with the agencies involved in medical emergency and rescue. The Master's ultimate responsibility and full-scale involvement in the process was emphasized. ■

AAUS - Chuck Mitchell

In 1976 Federal OSHA and the U.S. Coast Guard issued draft emergency standards covering commercial diving operations. The driving force behind these standards was that the commercial diving industry had experienced unacceptable levels of employee injury, primarily in North Sea oil exploration work. For the purposes of these standards, commercial diving was defined as 'those activities in which there was an employee/employer relationship.' This categorization included diving by scientists.

The scientific diving community reacted vigorously, pointing out to OSHA that it had been self-regulating since 1951, had an excellent safety record, and that some of the standards required by the OSHA standards were both inappropriate and unsafe. Upon receipt of this information, OSHA and the U.S. Coast Guard indicated that scientific diving would be exempt; however, when the standards came out in 1977 scientific diving had been removed from the U.S. Coast Guard documents but was still included in OSHA's regulations.

Because Federal OSHA recognizes individual state OSHA organizations, California, with its closely knit scientific diving community, prepared unique standards for their own state. These standards were approved, and the federal government allowed the national issue to be reopened. The work-loss-injury rate quoted for scientific divers at that time was just under that for bankers: 0.0037/200,000 man hours. In consideration of these data, scientific divers were finally exempted because of their decades of self-regulation and maintenance of in-house standards covering operations, training, and individual diver control over the operation.

AAUS was formed in 1977, and incorporated in 1981 in the State of California as a nonprofit organization. Its scientific diving safety standards are generic; they cover certification of scientific divers and operation of scientific diving programs. They do not cover specific types of diving such as shipboard operations. They include minimum standards for such things as diver training levels and medical exams. Specific types of diving information are included in different publications, (e.g., Blue-Water Diving, Diving Computers, Biomechanics of Ascents).

AAUS standards, initially issued in the early 1980s, are the scientific community's accepted diving standards. AAUS includes Individual Members from almost one hundred institutions. Thirty-one marine research institutions are either Organizational Members or are in the process of becoming Organizational Members of AAUS. For an institution to qualify for membership, it must have a diving safety manual which meets the minimum AAUS standards. This document is reviewed by the AAUS Standards Committee before the institution becomes a member and before reciprocity with other Organizational Members can be expected. Reporting of diving and accident statistics is required. AAUS also acts as a clearinghouse for information as well as a resource for statistics and scientific/technical information. The standards are in a constant state of review. A second edition has been issued, and revisions concerning medical standards are underway.

The organization is all volunteer and is self-supporting in both its conferences and publications through dues, registration fees and publications sales income. It has an ad hoc representative on the executive committee of the UHMS. While board meetings take place four times a year, there are also regular committee meetings. Chuck Mitchell (Marine Biological Consultants Applied Environmental Sciences) is the current elected President, with Mike Lang (Scientific Diving Officer at the Smithsonian Institution) being the President-Elect. There is also an elected Vice President and Secretary. Since 1980 the organization has held an annual symposia at various locations throughout the country.

The typical symposia proceeding (Appendix D: AAUS Bibliography, page 72), available at the annual meeting, is on the order of 300 pages with papers that cover scientific results, operational procedures, medical requirements, technological improvements, ship design, etc. Additionally, there is a quarterly newsletter. (It was pointed out that UHMS also produces documentation on NITROX, diving accident management, oxygen treatment, etc.) AAUS estimates that at least ten percent of its members' annual diving is done from shipboard, frequently from vessels smaller than those in the UNOLS fleet.

One problem related to the use of AAUS standards occurs when science divers are involved with more than one agency on a research project such as those involving both NSF and NOAA. Frequently, the organizations involved will be faced with operational conflicts stemming primarily from differences in the details of each agency's approach.

With multi-institutional diving, the Principal Investigator is required to provide documentation, on all cruise research divers, to the lead institution's campus diving administration. This is much easier when the institutions involved are part of AAUS and thus have a framework for reciprocity. Typically on a shipboard diving cruise, the ship's Master and appropriate crew members are given an orientation lecture early on, covering expectations for support, description of actual diving efforts, and the expected response to emergency situations. ■

Science - Larry Madin, Alice Alldredge, Jon Witman and Bob Steneck

The scope of scientific diving includes operations, safety, and administrative issues. Science is significantly impacted by these elements, both in terms of what can be done and the costs of doing it. If the expense of the operation becomes too high, science capability suffers. The full spectrum of diving from ships in the open ocean includes blue-water diving and benthic subtidal activities. Many of these activities are conducted well offshore, some even from small boats. Of critical concern is diving in a remote location where one must rely on one's own resources in the event of an accident. This requires establishment and communication of reasonable safety procedures and common understanding of standards, and rules and regulations. Questions and concerns arise from selection of types of equipment, definition of lead institution, establishment of the individual in charge, and institutional certification of divers.

Research diving is labor intensive and often involves volunteers, some of whom are undergraduate and graduate students. Issues involved with certification, training, insurance, liability, and support of this subset of divers, while especially critical, are often ill defined. In some cases, the problem is alleviated by confining volunteer help to noncritical tasks such as working with collections, tank filling, etc.

There is a high degree of variation between cruises and between operators as to what science brings to ships as well as what ship operations bring to science. Inconsistencies exist relative to availability and configuration of critical tools such as air compressors, inflatable boats, outboard motors, tanks, etc. Typical emergency questions include: Is there breathing oxygen on board? Does it work? Who knows how to use it? Who is responsible in a medical emergency? Some diving emergency equipment such as medical oxygen has other applications, such as for heart attacks. Other questions: Should the scientists back up ship's gear with their own equipment? Who should equip the small boat with emergency equipment? What equipment is required? Discussion on who is responsible for provision and operation of small boats, the crew or science, is frequently an open issue. Protocol between ship Master and small boat operator involving such things as surface separation should be worked out ahead of time. This is especially critical when the ship is new to the area and the local conditions and may result in a conflict of judgment in which case the Master has the ultimate responsibility.

A good solution to a number of these problems is to have a pre-cruise consultation among the parties. The discussion of how the dives will be conducted should be quite specific, including details on equipment (i.e., compressor, oxygen tanks, sources, capabilities, and control). A pre-cruise conference with a full and clear checklist or agenda involving the Principal Investigator, On-Board Diving Supervisor and the Master is critical. It was noted that most ship accidents do not involve diving, and that statistic is biased by the relative low frequency of diving cruises.

While it would be nice to have agency diving support equipment available on all vessels, rather like CTDs are, this is unlikely due to infrequency of use. The problem of supplying equipment can be lessened by the availability of fully equipped diving vans and designation of specific vessels for diving cruises.

A CTD is an electronic instrument that, as it is lowered through the water on a cable, simultaneously measures conductivity, temperature and depth. While instruments are occasionally supplied by individual investigators, they are more often part of a pool of oceanographic equipment that are available on a rate-basis to researchers using a given ship.

There may well be different appreciations of equipment condition and suitability by the ship and the diver, especially regarding items such as compressors and small boats. The use of both air quality determination equipment and emergency oxygen requires specialized training. Interesting questions arise such as what is the difference between welding oxygen and medical oxygen? The only apparent difference is that medical oxygen requires that the tank must be completely emptied and refilled rather than just 'topped off' in order to assure that impurities are not present in the tank. Some states require prescriptions for medical oxygen.

Discussion

Shipboard diving safety is not a new concern. Documentation relating to techniques goes back to the late sixties and early seventies (Appendix E on page 83: Historical Shipboard Diving Procedures). Many of the items in the various standards, as well as ideas that are brought up at this workshop, have been informal standard operating practice for many years.

Because ship inspection teams often look superficially at diving capability, a more detailed review appears warranted. This review should concentrate on the diving equipment and the ship equipment (i.e., small boats and motors) as well as procedures for use and access to accident-response equipment. When the shipboard inspection program was first implemented, some operators were concerned that deficiencies would subject them to undue criticism. However, what actually happened was that ship quality and safety improved.

It is highly desirable for the Master, Chief Engineer, Diving Safety Officer, On-Board Diving Supervisor and the Principal Investigator to conduct a formal walk-through of the ship's equipment needed by the divers (e.g., small boats, crane). This process is difficult to implement when scientific parties and ships meet for the first time at a foreign port.

A critical issue for shipboard diving is special personnel. Due to the limited number of berths, establishing a separate requirement for a person whose sole task is that of On-Board Diving Supervisor can be a hardship.

The use of volunteer personnel in support of research diving is a complex issue. At the University of California, volunteers are listed as unpaid employees of the University. This allows them coverage under Workmen's Compensation. The volunteers' background, experience and certification is reviewed by the campus diving administration. They must pass a physical exam (often at their own expense), a written exam, and two monitored dives before being certified. Volunteers are not permitted to serve as an On-Board Diving Supervisor. WHOI issues a temporary diving permit but does not assume the Workmen's Compensation coverage burden unless compensation is involved. The inconsistency of these practices is illustrative of the differences between state and private institutions.

When it is determined that a dedicated On-Board Diving Supervisor is required on a cruise, salary and expenses may (or may not) be provided by the grant or the operating institution. Principal Investigators, however, frequently appear to be unaware of these additional ship-use costs. Better pre-cruise coordination and uniform user manuals should clarify the situation. It is impossible to assume the availability of the lead institution's Diving Safety Officer as On-Board Diving Supervisor for extended cruises because of simultaneous land-based diving or other activities. Uniformity in diving support requirements across the fleet is also highly desirable to avoid Chief Scientists' shopping for the 'cheapest set of rules.'

In the case of NOAA, which runs its own ship fleet and stages cruises on non-NOAA vessels, On-Board Diving Supervisors (who are NOAA employees) are provided without charge. This is in contrast to NSF where ships are institutionally operated through a grant, and mission-specific elements are funded through the science program.

It must be recognized that there may be dramatic differences in constraints, even for the same ship, operating close to an industrialized shore compared to a remote area beyond helicopter evacuation range. The suggestion was made that the proposal peer review process, when diving is involved, could benefit from review of diving operational safety and feasibility (not scientific merit) by a Diving Safety Officer from an RVOC institution, in a manner analogous to the 'compatibility' portion of the ALVIN Review Committee's (ARC) review of proposals.

The ALVIN Review Committee is a National Oceanographic Facilities committee of UNOLS. It was established for the purpose of considering proposals for ALVIN submersible use and recommending programs to be scheduled. In recommending the allocation of ALVIN time, the ARC acts primarily on the scientific merit of the proposed research and its compatibility with ALVIN and ALVIN's support systems.

One way of obtaining access to complex technologies such as NITROX is NOAA's National Undersea Research Center (NURC) program at University of North Carolina - Wilmington (UNCW). UNCW provides on-board expertise, training and all the unique gear. The use of NITROX allows the scientists to almost double their bottom time and may be a useful technique for NSF-supported vessels. Though expensive when compared to conventional scuba, NITROX is very cost effective when viewed in terms of in-water research time available per cruise day. There is not yet a critical mass of users within the academic diving community to warrant the development of such a facility within UNOLS; however, the participants expect that such proposals will be received by NSF in the future.

The NURC program is a system of undersea research facilities funded by NOAA and operated through the University of Alaska, the Caribbean Marine Research Center, the University of Connecticut, the University of Hawaii, and the University of North Carolina at Wilmington. These facilities make available research facilities including submersibles, ROVs and advanced scuba and surface supplied diving systems.

NOAA and Harbor Branch Oceanographic Institution have requirements for pre-cruise training relative to emergency actions. The specific accident management training is done over two to three days in the spring of each year. They also conduct on-board emergency drills and require medicals and check-out dives for use of NITROX gear.

Within NOAA check-out dives for air scuba are not required. They are called for only where special equipment such as dry suits are to be used or if diving frequency or interval requirements are not met. The requirement for 12 dives per year is designed to assure that a diver is competent and in good physical condition. In temperate climates this can be a problem when the dives are clumped into the warm months. Reciprocity of diver credentials between NOAA and AAUS would be desirable but is not being formally pursued at this time.

AAUS provides a framework for an efficient reciprocity between institutions relative to basic and specialty diving competence. Standardized reporting and perhaps a 'scientific diver passport' or card suitable for all Organizational Members is currently underway. The card would contain the individual's name and institution and would signify that the diver has been trained and will operate under AAUS standards. Any specialized training would be listed as well. Establishment of a central data repository is most desirable. While such a mechanism provides entre to initially qualified research divers, it cannot provide an assessment of current capability, a matter to be addressed by the Diving Safety Officer prior to the cruise.

Emergency Medical Technicians are carried on some research vessels. These individuals are typically members of the ship's crew who have received special medical training and who take on this responsibility in addition to their normal duties. There is a special category of EMT - the Diving Medical Technician (DMT). The DMT program was designed to meet the specialized medical needs of the offshore diving industry. While, to the best of the workshop participants' knowledge, there are no DMTs among the crew members of the UNOLS vessels, at least one scientific technician has received this type of training.

A checklist for cruise diving procedures should be made a uniform requirement for the entire academic fleet. The checklist should include procedures, responsibilities, schedules, sequences, and documents. The impact of additional diving requirements, paperwork, and infrastructure is significant for smaller institutions. The repetitive paperwork load should be reduced. For instance, in cases of doing interagency work, multiple diving logs and physical examination requirements, such as yearly blood typing, should be avoided. A national medical database, perhaps maintained by AAUS or the Medical Advisory System, could be made available to institutions in need through FAX. Diving EMTs, while useful and desirable, probably do not offer enough of an advantage over regular EMTs to merit that as a requirement.

The question of telling a physician the details of how to do his job was broached. If a campus diving administration is willing to accept the physical examination results, why should it constrain the physician? The diving medical exam has eliminated a few candidates on the initial exam. Few, if any, problems have been picked up on renewal physicals. The guidelines should not dictate to the physician what to do, but should identify the conditions that might present medical problems for the diver. An ideal physician for this service would have recent training in diving medicine.

The question of whether or not the ship should conduct other activities during diving operations (i.e., hydrocasts and netting) was discussed. On-site consultation between research divers and the Master appears to be the best method of resolving this type of conflict, though in general it is considered preferable to constrain the ship from doing anything that could preclude its ability to move rapidly in an emergency. A surfaced diver with a problem, while the rest of the team is still below, compounds the difficulty of bringing a rescue vessel into the area where divers will soon surface.

In summary, a scientist needs the ability to plan research and to plan cruises in such a way that there are no on-site surprises and there is efficient interaction with the small number of other people (i.e., Diving Safety Officers, ship operations people, and agency personnel) critical to the mission. ▪

Section Two:

Safety Issues

Authority and Responsibility

Prepared by Phil Sharkey and Jack Bash

The session on Authority and Responsibility issues was wide ranging and included many examples of problems drawn from past experience. The workshop participants read over the current Section 15 of the *UNOLS Shipboard Safety Standards* and discussed its advantages and disadvantages. There was agreement that the Section 15 needs revision and that it could be a primary vehicle for creating a clearer definition of shipboard diving authority and responsibility. There was little controversy over the exact direction that a revision should take. It was felt that the current Section 15 of the *UNOLS Shipboard Safety Standards* should be revised to:

- Clarify the definitions of authority and responsibility.
- Assist the Master's understanding by defining cruise participants' jobs. In this way the Master's task changes from having to get these things done personally to assuring himself that others have gotten them done.
- Include a requirement for appropriate personnel to provide the Master with a detailed pre-cruise briefing.
- Require that appropriate personnel provide the Master with regular briefings during the cruise concerning the details of the diving operation.

There were disparate opinions concerning the precise wording of the proposed revision. An ad hoc group undertook carrying these concepts forward into a full revision of Section 15. The subgroup's work was reviewed by the entire workshop, and it is recommended that it be forwarded to the RVOC for coordination within the RVOC of their revision of Section 15 of the Research Vessel Safety Standards. This revision would then go to UNOLS for final approval and promulgation. The text of the suggested revision follows on page 25.

Additional observations, suggestions and questions included:

- It should be recognized in planning and documentation that the Principal Investigator and Chief Scientist are not always the same person. A single cruise may have several projects (and several Principal Investigators) aboard, but there is only one Chief Scientist.
- Most of the ship-related pre-cruise decisions are made by the Marine Office since the Master is at sea. The Marine Office, via electronic contact, can review these decisions with the Master to keep him informed and receive his comments and suggestions. During the cruise the Master may be required to make decisions relative to situations not anticipated in the Pre-Cruise Dive Plan.
- The more information that is available to the Master, the more helpful he is able to be.

- Masters are uncomfortable with diving because they are in charge of a vessel with divers on board and the diving safety protocols are not clear in their mind. Masters are often not fully aware of the details of the diving operation and thus do not know how, specifically, they should operate their ship with regard to divers in the water.

- The number of UNOLS ship-operating institutions without a campus diving administration should be determined. These institutions should establish such boards following the AAUS model.

- If there are UNOLS ship operating institutions without such a campus diving administration, should diving cruises be conducted from their vessels?

- If diving cruises are to be conducted when the operator does not have a campus diving administration, what are the details of responsibility and authority with respect to the diving operation?

- The general practice (within UNOLS) is that the Master receives a letter (or copy of a letter to the Marine Office) from the operating institution Diving Safety Officer listing the approved divers and a plan describing the nature of the diving. This letter also provides the name of the person who is the On-Board Diving Supervisor appointed for that cruise. This practice should be standard procedure for all UNOLS institutions.

- Development of educational materials concerning research diving should be encouraged, including but not limited to training manuals, slide shows and videotapes that are aimed at helping the Master and crew to understand research diving in general, as well as the specifics of research diving operations for the upcoming cruise.

- A list of protocols for various diving situations and respective responsible individuals should be developed. It should be no more than a page or two of guidelines and should detail those persons who are ordinarily considered responsible for given items.

- The relationship between the Master and the On-Board Diving Supervisor needs to be clearly defined. This might be modeled on the relationship between the Master and the Chief Engineer. ■

Draft Section 15 - *UNOLS Shipboard Safety Standards*

15: Diving Operations

15.0 Policy: Scientific diving is a normal part of oceanographic research vessel operations. Such diving conducted from a University National Ocean Laboratory System (UNOLS) vessel must be under the auspices of a diving program that meets the minimum American Academy of Underwater Sciences' (AAUS) *Standards for Scientific Diving Certification and Operation of Scientific Diving Programs.* Operators without a program may accommodate scientific diving cruises which are under the auspices of an institution with such a diving program.

15.1 Diving Procedures, Rules and Regulations: For all cruises a single lead institution's campus diving administration will be designated. This is usually accomplished by agreement of all campus diving administrations involved. Items which refer to the campus diving administration may, in fact, be the concern of the Diving Safety Officer according to the practices of the institutions involved. The procedures, rules and regulations that govern the diving operation are those of the designated lead institution, subject to the approval of the operator's Marine Office.

15.2 Cruise Planning: In a timely fashion prior to the cruise:

1) The Principal Investigator will insure that a cruise dive plan is supplied to his or her campus diving administration who will forward the cruise plan, once approved, to the lead institution's campus diving administration. The dive plan, prepared in a standard format includes: diving credentials for all diving members of the scientific party, detailed operational plans, emergency plans including accident management and emergency evacuation protocols, a list of needed medical supplies, a specified quantity of medical grade oxygen with a positive pressure demand delivery system, and required diving support equipment (e.g., small boats).

2) The lead institution's diving administration will, after approving this plan, forward it to the operator's Marine Office.

15.3 Cruise Personnel:

1) The Master has responsibility for the safety of all activities aboard including diving (Section 13.4).

2) The Chief Scientist is responsible for the co-ordination and execution of the entire scientific mission (Section 13.5).

3) The Principal Investigator of the diving project (who may or may not be the Chief Scientist) is responsible for the planning and co-ordination of the research diving operations.

4) The On-Board Diving Supervisor will be proposed by the Principal Investigator and approved by the lead institution's diving administration. The On-Board Diving Supervisor is responsible for the execution of the research diving operations in accord

with the cruise dive plan. He or she has the authority to restrict or suspend diving operations and alter the cruise dive plan in consultation with the Master and the Principal Investigator/Chief Scientist. The On-Board Diving Supervisor's responsibilities include:

A) Meeting with the Master and Chief Scientist to review the cruise dive plan and emergency procedures prior to diving.

B) Remaining in regular communication with the Master on the progress of the research diving operation.

C) Assuring that both the lead and operating institution's diving manual are available to the scientists and crew aboard the vessel.

D) Inspecting high pressure cylinders and breathing air compressors to assure that they meet the lead institutions' standards.

5) Research Divers must recognize their individual responsibility for their safety. ■

Multi-Institutional Cruises
Prepared by Larry Madin

The simplest diving cruise is when the scientific party members are all from a single institution, and are going out on a ship operated by their home institution. It is increasingly the case that the science party includes participants from several institutions, including foreign institutions and institutions without formal diving programs. There may even be some volunteers or observers with no institutional affiliation. The ship may be operated by still another institution, which may or may not have a diving program or regulations appropriate to the scientific diving planned.

The procedure for handling these situations that has developed informally over the last few years works well. It was the consensus of the group that this should continue, as formalized in the revised texts of Section 15 of the *UNOLS Shipboard Safety Standards* (page 25) and Chapter 14 of the *RVOC Safety Training Manual* and are reflected in the proposed Pre-Cruise Dive Plan Form (page 29).

The roles in a multi-institutional diving cruise include the Project Principal Investigator, the cruise Chief Scientist, the On-Board Diving Supervisor, the science party members, the vessel Master, the research vessel operator and the campus diving administrations and Diving Safety Officers of all the institutions under whose auspices these individuals work.

The model process for planning a diving cruise involving all these parties is :

A) The Principal Investigator of the project requiring diving is responsible for choosing the scientific divers and consulting with the cruise Chief Scientist (if a different person) and his or her home campus diving administration on the selection of a lead institution's campus diving administration and an On-Board Diving Supervisor.

   1) Commonly, the lead campus diving administration will be that of the institution operating the ship, but if the operating institution lacks a campus diving administration, or does not have regulations and procedures that cover the proposed diving (e.g., tethered blue-water or NITROX), then another campus diving administration might be proposed as the appropriate lead group. In any case, the campus diving administrations of the operating institution and the other institutions involved must agree with the choice of lead institution's campus diving administration.

   2) The On-Board Diving Supervisor will often be the Principal Investigator, the Chief Scientist or a member of the science party, but it may be another person approved by the lead institution's diving administration or the operating institution. Funding for the On-Board Diving Supervisor (e.g., salary, travel, special equipment) has been an area of conflict and needs to be clearly defined.

   3) Decisions made should be agreed to by all parties well before the cruise.

B) The Principal Investigator ensures that each diver has submitted the necessary credentials to his or her home campus diving administration, who can then provide a letter to the lead institution's campus diving administration certifying the qualifications of the diver.

1) Divers who do not have a home campus diving administration need to obtain research diver status within a formal research diving program. This can be accomplished by affiliating with the research diving program at the Principal Investigator's home institution, the operator's institution or another institution with such a program.

2) The required credentials normally include research diver certification, a current physical exam, recent diving logs, and evidence of appropriate insurance coverage. Sometimes the home or lead institution's diving administration may require additional information, forms or actual check-out dives.

3) Credentials of foreign divers (i.e., CMAS Scientific Diver Brevet) may be sent to the AAUS Standards Committee for an explanation of the equivalency of their qualifications with AAUS standards.

CMAS is the acronym (in French) for the World Underwater Federation. This international organization has a Scientific Committee that issues an internationally recognized scientific diver certification based on a diver being a legitimate researcher and meeting a set of equivalencies of training and experience.

4) The cost of special training, travel, equipment, etc., necessary for a scientific diver to meet the requirements of the lead institution's diving administration are normally borne by the science project in which the diver is participating.

C) The lead institution's campus diving administration summarizes information pointed out in (A) above in a letter to the ship operator (Marine Superintendent and Master). This letter appoints the On-Board Diving Supervisor and lists the other divers, their certification limits and any regulations or restrictions particular to the planned diving.

'Marine Superintendent' is used as a generic term. The individual holding this position is referred to by different terms at different institutions (e.g., Port Captain, Marine Manager).

1) All diving on the cruise is under the supervision of the On-Board Diving Supervisor, and follows the regulations of the lead institution's diving administration and any special restrictions.

2) The On-Board Diving Supervisor is always authorized to restrict diving activity during the cruise and under special circumstances to advance diver certification levels and even certify research divers.

D) The cruise Chief Scientist prepares and submits to the lead institution's diving administration and operating institution a Pre-Cruise Dive Plan on the suggested standard form (page 29).

E) At the beginning of the cruise, the On-Board Diving Supervisor meets with the Master and Chief Scientist to review both the diving and emergency plans.

There may occasionally be situations that are not explicitly covered in this procedure, but the general mechanism of communication among the parties involved and final approval by the lead institution's campus diving administration should work in these cases as well. ■

Pre-Cruise Dive Plan		**Research Vessel**	
Chief Scientist		**Cruise Number**	
Cruise Start		**Cruise End**	
Operating Area		**Lead Institution**	
Diving Site Locations			

Dive Plan (Check all that apply)

Type of Diving		**Diving Mode**
☐ Bottom oriented (near shore)	☐ Repetitive diving	☐ Open Circuit SCUBA
☐ Bottom oriented (off shore)	☐ Multi-day diving	☐ Mixed Gas (NITROX)
☐ Buoyed down-line at site	☐ Cold water	☐ Mixed Gas (other)
☐ Blue Water - tethered	☐ Under ice	☐ Surface Supplied
☐ Blue Water - untethered	☐ Cave	☐ Dry Suit
☐ Night diving	☐ Wreck	☐ Diving Computer
☐ Decompression diving	☐ Other:	☐ Other:

Maximum Depth of Dives:		**Diving Tables used:**			
☐ 30 ft.	☐ 130 ft.	☐ U.S. Navy	☐ Huggins'	☐ Canadian	☐ Royal Navy
☐ 60 ft.	☐ 150 ft.	☐ Swiss	☐ NAUI	☐ PADI	☐ Other:
☐ 100 ft.	☐ 190 ft.	☐ Diving Computer Model:			

Possible Hazards

Physical		**Biological**	
☐ Strong Currents	☐ Low visibility	☐ Sharks	☐ Stinging organisms
☐ Fog	☐ Pollution	☐ Spiny organisms	☐ Other:
☐ Ice	☐ Other:	☐ Large ugly marine mammals	

Briefly describe scientific diving procedures to be used on cruise (i.e., Special diving protocols, collection methods) and typical daily diving schedule (time & duration of dives)

Personnel

Supervisors	Name	Phone	TeleMail	Diving on cruise?	
Chief Scientist				☐ Yes	☐ No
				List below also	
Principal Investigator				☐ Yes	☐ No
				List below also	
Diving Supervisor				List below also	

Participating Divers		Address	Certification	
Name	Institution		Depth	Exp. Date

Non-Diving Support Personnel		Address	Function
Name	Institution		

Equipment and Personnel Needs			Supplied by		
Item or person needed			Science	Ship	Other
Scuba tanks	Number:		☐	☐	
	Size:				
Compressor	CFM:		☐	☐	
	Pressure:				
Tank Filling Cascade	Size:		☐	☐	
	Pressure:				
Dive Boat	Size:		☐	☐	
Dive Boat Motor	Size:		☐	☐	
Lifting Harness for Boat			☐	☐	
Emergency O_2	Amount:		☐	☐	
Demand valve for O_2			☐	☐	
Diving Computers	Model:		☐	☐	
	Number:				
Boat Operator			☐	☐	
Emergency signaling device	Type:		☐	☐	
Diving flag	☐ Alpha	☐ U.S.	☐	☐	
First aid kit			☐	☐	
Portable O_2 kit			☐	☐	
Radar reflectors	Type:		☐	☐	
Diver recall device	Type:		☐	☐	
Other			☐	☐	
			☐	☐	
			☐	☐	
			☐	☐	
			☐	☐	
			☐	☐	
			☐	☐	
☐	Emergency Plan Appended				
☐	Emergency Evacuation Plan Appended				

Small Boats and Small Boat Operators: Are There Adequate Rules and Guidelines for the Use of Small Boats Launched From Research Vessels?

Prepared by Tim Askew

The primary issue is whether or not adequate rules and guidelines presently exist in the *UNOLS Shipboard Safety Standards*, the *RVOC Safety Training Manual*, and/or the *AAUS Standards for Scientific Diving Certification and Operation of Scientific Diving Programs* covering the use by divers of small boats launched from research vessels.

Specific questions are:

1) Are diving-related small boat standards needed?
2) If so, what should these standards cover?
3) What types of small craft are best for the diver/ship?
4) What qualifications should a boat operator have?
5) Should the boat operator be a crew member, a member of the science party, and/or a diver?

Question 1: Are diving-related small boat standards needed?

The consensus is that rules and regulations exist, but these are not consistent or consolidated in one easy format. Most institutions have a manual with a section on small boats, normally outlining small boat operations, boat operator requirements, U.S. Coast Guard required equipment and safety procedures. These procedures often pertain to land-based operations and sometimes ignore small boats launched from larger vessels.

Most vessel operators have rules and regulations pertaining to small boat operations. These are written and unwritten, and are slightly different for each organization. There seems to be a wide range of procedures when it comes to scuba diving activities conducted from small boats launched from larger vessels either in the open oceans or in more protected areas.

The operators, at the workshop, recommend basic written standards pertaining to all small boat operations especially diving-related ones. In addition to these standards, each organization might have certain rules that only pertain to them or their operation.

Question 2: If so, what should these standards cover?

Small boat standards should cover all aspects of small boat operations including the following:

A) Operator Requirements

1) Certification (i.e., U.S.C.G., institutional, other).
2) At sea check-out for operator consisting of launch and recovery, radio operation, emergency procedures, tending divers, approaching another vessel, etc.

3) Show proficiency in establishing relative position of the boat position by using available navigational aids (e.g., use of charts, compass, LORAN, etc.)
4) Demonstrate proficiency with all pertinent operational and safety equipment.
5) Indicate ability to use and negotiate expected environmental features (e.g., negotiate kelp beds and coral reefs, read water colors and depths).
6) Demonstrate expertise in following divers (e.g., following diver bubbles, float lines, etc.).

B) Operational Procedures

1) Launch and recovery

   a) Diving equipment in or out of boat during launch and recovery.
   b) Operator in or out of boat or skiff during launch and recovery. If so, the tackle must be man-rated.

2) Divers climbing in or out of small boat from mother vessel with gear on or off.
3) Divers entering or exiting the water, to or from a small boat with engine running or not running.
4) Lifejackets for operator and/or divers.

   a) Buoyancy compensators, wetsuits and drysuits as substitutes for lifejackets.
   b) Small boat size determines whether or not lifejackets can be carried (i.e., not enough room along with diving gear).

5) Radio Communications

   a) Reporting when divers submerge and resurface.
   b) Reporting if something looks amiss.
   c) Reporting status on a predetermined schedule.

6) Special Requirements

   a) Blue-water diving
   b) Diving out of sight of mother ship
   c) Cold water diving
   d) Operating in low visibility conditions: fog, haze, and night operations or any other condition that may reduce or hinder line-of-sight visibility.

7) Float Plans and Dive Plans: Generally up to diving party to fill out and have approved prior to leaving the mother ship; serves as notification to vessel Master that small boat will be required and where it is going.

8) Check List: Used by operator to ensure boat's operational status and presence of safety equipment.

9) Weather report and/or status, including sea conditions.

10) Emergency Procedures

a) Safety Equipment: could include any or all of the following: Radar reflector; Strobe lights; VHF radio with RDF (radio direction finder); Mylar Balloons; EPIRBs (Emergency Position Indicating Radio Beacons).
b) Method or procedure of recalling divers to surface.
c) Assistance to injured diver.
d) Disabled boat.
e) Loss of communications.

Question 3: What types of small craft are best for the diver/ship?

Most operators and divers feel that the inflatable boat is the most suitable for scuba diving operations. The most desirable inflatable is the hard bottom version, which provide a very stable platform. In addition, inflatable boats can take a considerable amount of abuse when alongside the mother vessel. Many operators use small to medium size *Boston Whaler*-type boats to support diving operations. These boats are adequate in most cases, and many vessels carry two boats: one inflatable and one *Boston Whaler*-type. Research divers in cold waters may require a larger boat due to the bulky nature of their protective suits and the amount of lead needed to offset their suits' buoyancy.

Engine/drive designs are available that improve on the relative hazards of propellers, such as jet drives or a protective shroud around a regular propeller. These designs should be considered whenever a motor or boat is replaced.

Question 4: What qualifications should a boat operator have?

Reference Question 2. In addition, qualifications may be determined by operating organization.

Question 5: Should the boat operator be a crew member, a member of the science party, and/or a diver?

The majority of the time, the boat operator is a member of the ship's crew, and therefore the Master of the vessel is assured of his/her qualifications. If a member of the science party is designated as a small boat operator, he/she must be able to demonstrate small boat operator qualifications to the satisfaction of the vessel Master. It is desirable, but not required, that the boat operator be a diver. If the operator is a diver, participation in diving operations should not allow leaving the small boat unattended.

Conclusions:

There appear to be two distinct views concerning small boat activities: one is the vessel operator/Masters' point of view, the other the scientists/users' point of view. The Master's concerns are centered around the small boat operator's qualifications, whereas operators from the user's organization may be fully qualified, yet not possess a document stating so. The scientists/users in many cases are competent and qualified small boat operators having been trained by their own organizations. However, their requirements may or may not meet the ship operating organization's requirements. Some science groups furnish their own boats and operators while conducting science missions from another organization's vessel, and in most cases their members do not possess a document stating that they are qualified small boat operators. This leaves the Master in the position of having to decide whether or not to accept a verbal claim that a person is qualified.

UNOLS vessels routinely conduct small boat operations. Each organization should have rules and regulations in place, and while many are similar, none are the same. There is a need for a common set of rules that all organizations can either follow or use as guidelines to further supplement their own regulations. These basic guidelines should be incorporated into the *UNOLS Shipboard Safety Standards* and/or the *RVOC Safety Training Manual.*

Diver Training and Evaluation Standards

Prepared by Chuck Mitchell and Phil Sharkey

The bulk of scientific diving experience is gained from operations in the near-shore environment involving small boats or shore-based diving. As was noted, 'Shipboard diving is quite different from small boat or shore-based operations and is, therefore, worthy of comments to aid the inexperienced.'[7] The protocol for diving operations from large oceanographic ships requires a higher level of skills and knowledge due to the more complex logistics and communication requirements and the increased safety margin necessitated by remote operations. This is true for both ship personnel and the scientific party.

The assumption that all members of such expeditions have been adequately trained and indoctrinated in the tasks to be performed may not always be valid because of ship or scientific party schedules. When it is perceived that personnel may not be qualified for the task to be performed, there is an added burden placed on the crew and operators of the vessels which may cause unnecessary workloads. Similar impacts are observed on the scientific party, who have not only the operational aspects to deal with but also the pressure of accomplishing the science.

Based on the collective experience of vessel Masters, Diving Safety Officers, and senior scientists, the following areas of difficulty have been identified:

- Insufficient planning.
- Conflicts in the evaluation of diving skills.
- Operational skills.
- Communications between all parties involved.

Evaluation of Basic Diver Skills

It is not uncommon for expeditions to include diving personnel from institutions other than the vessel operator. When such field efforts are planned, it is the responsibility of the Principal Investigator to assemble and review the participating divers' qualifications and proficiency level for the diving mode and task to be performed. This information is then forwarded to the lead institution's Diving Safety Officer for review and approval. At this point difficulties may arise from the use of different criteria for the evaluation of a divers' proficiency and skill.

The American Academy of Underwater Sciences sets forth standards for training and qualifying divers, and operating research diving safety programs[8]. Most of the UNOLS membership is active within AAUS, and UNOLS references in their own standards[9] the AAUS standards. AAUS standards cover basic diver training but do not directly address day-to-day shipboard scientific diving operations.

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7 'Shipboard Diving Procedures,' Stewart, J. R.: 1971, in Part III of 'The Scripps Institution of Oceanography Marine Technicians Handbook,' Institute of Marine Resources, La Jolla, CA. - Included in this report as Apendix E.

8 'Standards for Scientific Diving Certification and the Operation of Scientific Diving Programs,' Heine, J. (Chairman): 1989, American Academy of Underwater Sciences, Costa Mesa, CA.

9 'UNOLS Shipboard Safety Standards,' Section 15: 1889, University National Oceanographic Laboratory System, University of Washington, Seattle WA.

Research divers at AAUS Organizational Member institutions are provided with institutional 'diver certification cards' which indicate that their training corresponds to a consensual minimal level, that they have a current medical exam, and have maintained their skills by continuing their diving activity at or above a minimum defined level. The community's accident/incident experience demonstrates that AAUS standards are effective for shore-based scientific diving. It has always been the policy of AAUS that the specifics of the actual research diver training and qualification process, as well as the day-to-day operational procedures, are the responsibility of each diver's home institution. This provides the home institution with appropriate authority over its divers and allows each institution to ensure the skills and experience that are necessary to its diving operations and the particular environment in which their scientists are working. AAUS has sought to establish full reciprocity among institutions; however, there remain differences between the specific requirements and procedures of Organizational Members. This should not be viewed as negative, but simply as a reflection of how various institutions have approached specific problems in their operational environment.

It is often difficult for foreign divers and divers from institutions without an AAUS model research diving safety program to demonstrate (or document) their qualification for research diving cruises. Arrangements for the testing and certifying of such divers prior to a cruise involves either bringing the diver to a location where there is such a program or having the Diving Safety Officer (or a designated representative) travel to the diver's location. Both of these solutions can be expensive, time consuming and always raise the issue of who should pay for such services. An alternative is the inclusion of the Diving Safety Officer (or a designated representative) in the scientific party. This latter approach makes the researchers' ability to dive during the cruise uncertain (since the checkout dive does not occur until the start of the cruise), and may also be expensive in terms of funds (for travel and salary) and scientific berths.

The development of common policy approaches, criteria and evaluation protocols for the testing of the proficiency of shipboard scientific divers and support personnel is needed. This would alleviate the conflicts that sometimes occur between the visiting scientist and the host institution concerning both the evaluation of diver's proficiency for the task to be performed and the assignment of charges for such evaluations.

Evaluation of Operational Skills

As has been indicated above, diving operations from large oceanographic ships require additional skills for both ships' crew and scientific personnel. Logistics, communication and operations are generally more complicated for world-ranging vessels than for smaller coastal vessels. It is therefore imperative that all parties involved be versed and familiar with the tasks to be performed, and how those tasks will be accomplished. The initial measure of operational skill is most likely to be the submission of a complete and well formulated dive plan. This plan, submitted by the On-Board Diving Supervisor, must be reviewed with the vessel Master, as well as the Marine Office and Diving Safety Officer of the vessel-operating institution. Review of this plan can alleviate conflicts that sometimes arise due to differences in expectation between visiting scientists and the host institution with respect to operational protocols. Before diving operations begin, the Principal Investigator must meet with vessel crew who are expected to be directly involved with the operation, as well as with diving personnel, to review the dive plan and clarify lines of communication and authority. Emergency plans, which are an integral part of the dive plan, need to be reviewed and discussed at this time.

Development of New Training Standards

At present, the responsibility for establishing minimum training standards for scientific divers rests with AAUS. The implementation of these standards rests with the various campus diving administrations. When there is a call for a new diving procedure (and training for it), the steps often go this way:

A) A scientist identifies his or her need to dive under some special circumstance, with special gear and/or in a special way.

B) This scientist (and other researchers who want to use the technique) must convince his or her peers on the Diving Control Board that the use a new diving procedure is safe and warranted.

C) The researchers explore the ways other communities have used these procedures and, with the oversight of the campus Diving Control Board, either obtain training or develop new protocols.

D) As other researchers learn of the usefulness of the procedure, they convince their own Diving Control Boards of the need to use the procedures and the reasonableness of the way in which the procedures are currently in use at other institutions. At this time the procedures are often modified to adapt them to environmental conditions other than those for which they were developed.

E) If the use of these procedures spreads through the community, then the AAUS may hold a workshop or conference that results in a new community standard (See Appendices F and G: AAUS Guidelines for the Use of Diving Computers and AAUS Safe Ascent Recommendations on pages 85 and 86 respectively); or

F) If the new technique is only of interest to a few divers or universities, then they will, with the campus Diving Control Board, evolve and use those protocols individually.

Summary

Use of well developed and accepted community standards result in confidence that the diving and support teams are qualified to perform the tasks required. The process of staging a diving cruise would be facilitated by the development of consensual evaluation and operational standards for diving from academic research vessels similar to that now in existence for small-boat and shore-based diving. Such standards should be developed by Organizational Members of the AAUS who represent a cross section of vessel operating institutions and diving scientists. A critical test of the success of such future standards is the acceptance of them by the research diving community as would be demonstrated by the evolution of a community expectation the all UNOLS institutions be Organizational Members of the AAUS. ■

Emergency Plans
Prepared by Chuck Mitchell and Robert Sand

Medical emergencies arising from injury are a long standing problem for persons at sea due to the remote location. Traditionally, ships are equipped with basic medical supplies and equipment to provide first aid and stabilization of victims prior to their transfer to the nearest appropriate medical facilities. Ship's traditional protocols for handling such emergencies are well established. However, in the event of a diving accident, where an individual may require recompression and specialized treatment, sources of aid and medical support are limited and require additional planning consideration.

Written requirements for diving emergency plans go back to the first diving safety manual developed at Scripps Institution of Oceanography[10] in the early 1950s. This document, and all similar subsequent documents, have required that emergency plans exist for all diving operations, ship-based or shore-based. As a result, diving cruises have a specific requirement for the preparation of an emergency plan, '...emergency plans which are acceptable to the lead DCB and to the operator's Marine Office must be prepared.'[11] This requirement for more than an ad hoc plan does not exist for non-diving cruises.

'DCB' is the acronym for 'Diving Control Board' which is the title usually applied to the campus diving administration.

Diving emergency plans are specifically designed to respond to a diving accident and generally require identifying and verifying:

A) Mechanisms for establishing communication links to medical advisory care (phone numbers and/or radio frequencies for medical advice, U.S. Coast Guard, foreign coast guards).

B) Evacuation contacts (phone numbers and/or radio frequencies for coast guards, navies) and working aircraft evacuation ranges for the operational area of the cruise.

C) In non-US waters, location of operating hyperbaric chambers and appropriate medical support.

D) Level of on-board medical assistance available/required (e.g., CPR, EMT).

The emergency plan represents a data source for specific information on regional sources of emergency medical support and transportation. While sources of such information are readily available within the waters of U.S., support services in remote areas are frequently lacking. At present, information on available facilities and support is compiled and accumulated by Principal Investigators and Diving Safety Officers of individual institutions and receives limited distribution. Such information is an important planning element for researchers involved in diving operations in remote areas, and for reference during operations in the event of a diving accident. Ship and research personnel should conservatively assume that they must be self-contained to respond to emergencies while working in remote areas.

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10 'The University Guide for Diving Safety'. University Conference of Environmental Health and Safety Officers: 1967, University of California, Berkeley, CA.

11 'UNOLS Shipboard Safety Standards,' Section 15: 1989 University National Oceanographic Laboratory System, Seattle, WA.

Both facilities and support have to be integrated since the presence of shore-based recompression chamber facilities without medical support is of little use. As many evacuation options as possible should be documented. For example, within the service area of the U.S. Coast Guard, the U.S. Navy can also respond in certain situations as can various police departments. In addition, there may be private air ambulance services available. Medical information and support services such as MAS or Divers Alert Network (DAN) are available from the private sector, as well as the U.S. Coast Guard and U.S. Navy.

DAN is member-based public service organization headquartered at Duke University's F.G. Hall Hyperbaric Center. It sponsors conferences, distributes information and publications, and provides a free 24 hour hyperbaric medical consultation and referral service.

The driving issue centers first on a determination of whether the diving operations represent a unique set of requirements to the safe operation of the vessel and the health of crew and scientific party. If there are unique requirements, then clearly unique plans need to be made.

Even when diving operations do not present unique or complex accident management problems, they do represent an additional layer of logistical concern since research divers, when submerged, are not in direct contact with surface personnel. In the event of an accident, the victim will require extraction from the water and transport to the support vessel. After transfer to the support vessel, the emergency protocol is not different from that required by other medical emergencies: provision of first responder aid, stabilization of the victim, communication with medical support and advisory services, preparation for evacuation, and transportation to medical treatment facilities.

Inasmuch as the direction of, and authority over, all diving operations lies with the On-Board Diving Supervisor, he or she must assemble the information and protocols that go into the Pre-cruise Dive Plan.

Emergency Plan File & Database

To assist Principal Investigators, On-Board Diving Supervisors, and ship personnel in the formulation of an emergency plan, it is proposed that a centrally located file consisting of past emergency plans be assembled and kept by geographic area. Part of this file would be a collection of response charts, each annotated with the location of evacuation facilities. The response charts would be scribed with 'response-radii' indicating the geographic areas that are within specific expected air evacuation response times. It is not intended that these charts serve as an 'off-the-shelf' product that is routinely maintained and up-to-date. Rather, these charts would serve as a starting point to be updated by the On-Board Diving Supervisor prior to a cruise in the area to be covered. The file's contents would be catalogued in an on-line computer database so that those responsible for preparing emergency plans would know what information was available as a starting point. This file would aid the determination of what facilities and support would be available and the general protocol to be followed in the event of a diving accident requiring hyperbaric treatment.

In practice, even the most well conceived plans are subject to a host of factors over which vessel operators and scientific staff have little or no control. Historically, it has not been uncommon to have evacuations take many hours due to sea and weather conditions when only a few hours were anticipated. Additionally, medical information and support is sometimes not immediately available. Such occurrences serve to illustrate the need for alternative plans to minimize delays which could be life threatening.

Portions of the database are already available. Some lie within resource documents of the Undersea & Hyperbaric and Medical Society[12], Divers Alert Network[13], and certainly within the research diving safety programs and marine offices of UNOLS institutions and AAUS Organizational Members. These materials could be collated at (and made available from) the UNOLS office. They should be updated whenever additional material was accumulated.

To provide an effective, readily available database, pre-printed entry forms should be developed and provided to UNOLS for distribution to Principal Investigators. Principal Investigators would complete and/or confirm the data during the Pre-Cruise Planning phase.

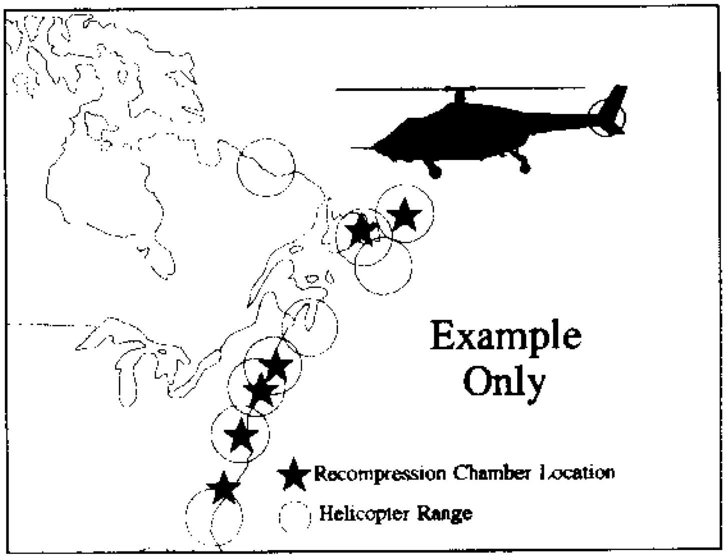

Figure 5: Sample chart showing recompression chamber locations and helicopter response areas.

<u>Summary:</u>

The Emergency Plan Database is a file containing a list of facilities and support services available by region. It would be utilized by Principal Investigators, Diving Officers and ship personnel as an aid in emergency planning.

What is proposed is a long-term dynamic program, capable of growing and becoming more refined as data are accumulated and assimilated. The assembly of such a database would best be accomplished by a group familiar with and sensitive to the requirements of both the vessel operators and the scientific divers. A 'response-radius' chart should be required for all diving cruises as should the use of a form like the one on the next page. The chart is filed by geographic area and the form is kept in an on-line database that could be queried by anyone putting together an emergency plan for a diving cruise.

[12] 'Hyperbaric Chambers in the United States and Canada' Batz, P. G. & Myers, R. A. M. (Eds): 1990, Undersea and Hyperbaric Medical Society, Bethesda, MD.

[13] 'The DAN Underwater Diving Accident Manual, Revised Edition.' Mebane, G.Y. & Dick, A.P.: 1985, Divers Alert Network, Duke University, Durham, NC.

<table>
<tr><th colspan="3">UNOLS Emergency Planning Form</th></tr>
<tr><td>Date:</td><td>Data Provided By</td><td></td></tr>
<tr><td rowspan="2">Operational Area</td><td>Latitude and Longitude</td><td></td></tr>
<tr><td>Standard Navy Ocean Area Designation</td><td></td></tr>
<tr><td rowspan="3">Primary Medical Information Service</td><td>Name</td><td></td></tr>
<tr><td>Address</td><td></td></tr>
<tr><td>Phone/Telex/Radio</td><td></td></tr>
<tr><td rowspan="4">Primary Evacuation Services</td><td>Name</td><td></td></tr>
<tr><td>Address</td><td></td></tr>
<tr><td>Phone/Telex/Radio</td><td></td></tr>
<tr><td>Range of Support:</td><td></td></tr>
<tr><td colspan="3">Medical histories should be registered with MAS</td></tr>
</table>

Recompression Chambers: Are They Needed on UNOLS Vessels During Diving Cruises?

Prepared by Bill Fife

The basic question is whether or not recompression chambers should be required for UNOLS ships engaged in diving cruises.

Basic facts and assumptions which bear on the problem are:

A) Based on the track record of all of the UNOLS diving operations, bends resulting from ignoring time and depth limitations are unknown. One instance of an incapacitating over-pressure accident has been reported in this program.

B) Diving operations conducted at sea by commercial diving firms and military units have traditionally had recompression chambers present. These chambers' primary function is less to provide an emergency treatment facility, than to permit surface decompression. Surface decompression is a technique where the diver exits the water prior to the completion of his or her decompression obligation and is immediately re-pressurized in a chamber. The diver then decompresses as the chamber is brought to sea level pressure. Because of its dangers, this is not an approved procedure within the scientific diving community.

C) The desirability of a recompression chamber in treating a case of decompression sickness (DCS) is not questioned, although it may be possible to successfully treat simple Type I (pain only), and even some Type II (Central Nervous System involvement) bends with oxygen and other field methods without a chamber being used. This will be discussed below.

D) If a chamber is present on a UNOLS vessel, trained personnel also must be aboard to operate it and to be inside attendants. Divers with some college education or technical training can quickly be taught to operate a treatment chamber, and Emergency Medical Technicians (EMT), Diving Emergency Medical Technicians (DEMT), or Cardio-Pulmonary Resuscitation (CPR) trained personnel can be trained to function as inside tenders. All of this presupposes that adequate medical advice is available.

The one incapacitating accident occurred in 1983. An analysis of this case reveals several contributing facts which should be noted:

A) The diver had been making repeated, multi-level, tethered bounce dives ranging between 50 and 80 feet of sea water (fsw); he ran out of air and was forced to make a free, possibly uncontrolled ascent. He was diagnosed as having subcutaneous emphysema.

B) There was no breathing oxygen or mask on board the ship. As a result, welding oxygen was administered through a cutting torch, first using cupped hands to direct it to his face, then by a styrofoam cup with the torch stuck through. It is doubtful if he received more than 50 percent oxygen at any time.

C) This diver had a previous history of air embolism in 1977 from which he made an apparently complete recovery without chamber treatment. His authorization as a research diver was canceled by his home institution. After several years of petitioning and medical review, his diver status was restored.

D) The circumstances surrounding this (and the previous incident) raise the question of the presence of the existence of a patent foramen ovale, a heart condition involving a small hole between the atria. In divers this may permit venus blood, containing bubbles that normally would be filtered out by the lungs, to pass through into the arterial side. These bubbles then expand on ascent and create a blockage of blood supply referred to as an air embolism.

Most of the workshop participants feel that there is no reason to require the presence of a chamber on UNOLS diving cruises. This opinion is based on the thousands of open-ocean dives made by research divers with no decompression incidents. A small minority of workshop members stated that a chamber should be considered whenever diving is being undertaken.

If, as a result of an unusual cruise requirement, it were desirable to place a chamber on a UNOLS vessel, and provisions made for proper procedures and properly trained personnel, the following points relating to the type of facility need to be considered:

A) Multi-place chambers. There is no doubt that, from the standpoint of flexibility of treatment, a double-lock, multi-place chamber is preferable.

1) The benefits of a double-lock chamber are:

a) Allow more than one diver to be treated simultaneously.

b) Allow one or more attendants to be present in the chamber. This is especially important in the event of a seriously incapacitated or unconscious patient.

c) Allow treatment at 165 fsw, which is indicated for air embolism.

2) The negative aspects of a multi-place chamber are:

a) The cost. A turn-key installation based around a 'used and in good condition' chamber and including compressors, installation, etc., would cost about $80,000. A chamber must be maintained year after year in a high state of readiness even though it may not be used, and must meet Coast Guard specifications and inspection. Minimum maintenance and upkeep would cost between $1,000 and $2,000 per year, exclusive of personnel and floor space.

b) The weight and size. This could range from a low of two to as much as twenty tons (five to six tons is likely) and could require 400+ square feet of floor space. An additional five tons of hardware would be needed.

c) The need for an air compressor which produces breathing-quality compressed air. This could cost from $6,000 to $27,000, used.

d) In most cases, storage tanks for compressed air to assure quick response time are required.

e) The periodic maintenance required. To meet Pressure Vessel of Human Occupancy (PVHO) specifications, every ten years the windows must be replaced and periodically the chamber must be tested hydrostatically. This last requirement necessitates that the chamber be filled with water. Deck loading must be considered, or the chamber must be removed from the ship at those times. If the chamber is reasonably portable, this may not present a problem.

B) Mono-place chamber.

1) Its advantages are:

a) It usually is compressed with oxygen and thus does not require a high quality air compressor and filter system.

b) It is smaller and lighter than a multi-place chamber and can be moved around.

c) Its cost may be less than that of a multi-place chamber.

2) Its disadvantages are:

a) Only the patient can be placed in the chamber. If the patient is unconscious or might aspirate vomitus, it will be difficult to reach him or her because the chamber **must not be decompressed** if there is a blockage of the airways, or if the patient is convulsing. It also may present problems of transferring a patient to a multi-place chamber.

b) It requires oxygen, which may be delivered in two ways:

i) Pressurize the chamber and flood it with oxygen. If this system is used, it may be necessary to carry liquid oxygen because this type of unit requires free-flow of oxygen throughout the treatment. (It probably would require about 20 bottles of high pressure oxygen to carry out a single treatment.) Further, when the liquid oxygen is stored, there is constant evaporation even though it is not being used. A single fill of a 50-gallon tank costs about $65-70 each, and unless the tank is purchased, there will be constant demurrage charges. One supplier charges $60 per month. Based on the previous track record of lack of bends, it is conceivable that the UNOLS program could have spent $20-40,000 on this cost alone without considering the initial cost of chambers. One such mono-place chamber now costs about $65,000, although this price could probably be reduced to about $7-$15,000, depending upon the type, sophistication and vendor.

ii) Deliver oxygen by mask, using a demand regulator. In this case, the chamber would be compressed with air. This requires an air compressor to be used. Such a compressor either must be non-oil lubricated or there must be an excellent air filter system to remove oil and carbon monoxide which often is produced in an oil-lubricated compressor. It would, however, reduce the requirement for oxygen storage.

c) Most mono-place chambers have a maximum operating pressure equivalent to 60 fsw, although it may be possible to have one built that will go deeper. The use of 60 fsw for treatment of air embolism is questioned by some physicians, but others are using it for embolisms with success.

d) Evacuation of a victim from the chamber to another facility is very difficult. Once treatment is begun in a chamber, it usually must run to completion.

There are three items a Principal Investigator or Marine Superintendent should consider when deciding to place a chamber aboard a UNOLS vessel for a specific cruise:

A) Distance to a hyperbaric chamber: It must be constantly emphasized that diving has risks which the diver cannot avoid assuming. Having the best chamber and most qualified attendants immediately available cannot assure that the diver will not suffer serious or fatal consequences. Some neurological problems can become irreversible within a few minutes, and under such situations, even an immediately available chamber may not prevent serious consequences. No data exist which justify any specific permissible delay time for over-pressure injuries, Central Nervous System (CNS) or vestibular bends. Divers treated as long as several days after injury have made an apparently full recovery from Type I. An arbitrary time of three hours has been set by some physicians as a permissible time for treatment delay. Other physicians feel that if air evacuation or some other means of transportation is not practical within six hours, the probability of successful treatment is diminished.

B) Amount of Nitrogen Uptake: This is a function of the depth and length of dives as well as the frequency of diving. It is clear that the risk of bends is greater the deeper the diver goes, the longer he stays and the more frequently dives are conducted.

C) Risk of embolism: It is possible for a diver to embolize as a result of a breath-holding ascent from three feet to the surface in some circumstances. It is also possible that the diver may have a patent foramen ovale between the atria of the heart. Although a patent foramen ovale has been found in a large percentage of divers who have developed Type II bends, if a diver has a long history of diving without undeserved bends, many physicians feel it is unlikely that he or she has such an abnormality. A caution about this condition should be included in the diving waiver so that all divers are made aware of this newly detected problem and could have this checked if they felt it were a concern.

Decompression injuries, also known as the 'bends,' are divided into two different types:

1) 'Type One Bends,' which have no neurological symptoms, result from bubbles in skin capillaries or joints and typically cause a skin rash or joint pain; and

2) 'Type Two Bends' which are much more serious and result from bubbles effecting nerves or the organs of balance in the inner ear.

Prior to considering a chamber, thought should be given to other ways of providing a greater operational safety factor. The advantage is that these ideas are preventive rather than corrective. Several which should be considered are:

A) The use of in-water oxygen decompression. **This is not in-water treatment of bends**. This technique was used successfully in 1988 for over 3,000 safe two-a-day decompression dives to depths between 160 to 190 feet by the Department of Nautical Archaeology at Texas A & M University. Decompression tables for this technique were developed by Dr. Vann of Duke University. The present diving tables used by UNOLS (U.S. Navy or more conservative) are highly reliable. However, an additional safety factor would be obtained by using in-water oxygen at 20 fsw. The level of oxygen exposure in this procedure does not create a danger of oxygen toxicity. It might, however, justify an oxygen toxicity tolerance screening test on divers. The total cost of in-water oxygen decompression is far less than that of a recompression chamber.

B) Use NITROX breathing mixture in conjunction with air-based tables. This would cost more than simply using oxygen in the water, but is a viable breathing gas alternative. It would require some additional training, and any good diver could master it. It is clear that using an enriched oxygen mixture will not guarantee against bends, although tests have shown that it adds an extra safety factor if used with air tables at appropriate depths.

C) Screen all UNOLS divers for the presence of a patent foramen ovale as a part of their pre-diving physical examination. Such a screening can be done by some physicians. Here again, although the cost would be several hundred dollars, it might reduce the possibility of an unexplained case of bends. It should be pointed out, however, that probably many divers are diving successfully with a foramen ovale that is not sealed. One physician who discussed this is of the opinion that the data so far available do not warrant wide screening of divers.

D) Train personnel to be able to administer intravenous liquids such as Dextran. Research at Texas A & M University demonstrated that, in most instances, doppler detectable bubbles in goats with bends were reduced and even disappeared. This idea needs to be studied further on humans.

Conclusions:

Careful analysis of more then 40 years of research diving efforts does not, at this time, indicate a safety problem that dictates either a requirement for the installation of a chamber on a UNOLS vessel that is conducting a diving cruise or the use of the methods of increasing safety margins that are detailed above. Given the excellent past record and careful nature of UNOLS diving, it is unlikely that a requirement for a chamber will be warranted in the future. However, data on the question of appropriate safety margins should continue to be collected and reviewed.

Recommended Actions:

There are three categories of recommendations:

A) Chamber requirements: In view of the past UNOLS experience, no chamber should be required for diving cruises. However, a chart of all bodies of water contiguous to the U.S., identifying the location of available shore-based treatment chambers, together with information on the availability of evacuation equipment, and reaction time for emergency evacuation should be prepared and reviewed to determine possible evacuation timing.

B) Promotion of diving procedures that would further increase diving safety:

1) In addition to the UNOLS requirements for adherence to the AAUS research diving standards, the UNOLS research diving community is encouraged to utilize the guidelines developed at the American Academy of Underwater Sciences workshops (e.g., Diving Computers, the Biomechanics of Safe Ascents).

2) In-water oxygen decompression should be considered as a way of providing an extra safety margin. This might follow the tables developed by Dr. Richard Vann at Duke University, and currently used by the Institute of Nautical Archaeology. This research should assess the added safety factor resulting from the use of in-water oxygen for decompression. **Note: This is not in-water treatment of decompression sickness.**

3) The use of NITROX breathing mixtures for some UNOLS diving should be considered. An assessment of the technique should include consideration of the amount of added safety in view of the type of diving taking place on UNOLS ships, as well as the added cost over air diving.

C) Encourage future research aimed at:

1) Developing new techniques for detecting patent foramen ovales or other arterio-venous shunts.

2) Determining if on-board oxygen generators would be cost effective, and what if any difficulties would be presented by the presence of five percent argon in this oxygen. A study also should be undertaken to determine if such an oxygen generator would be practical for oxygen supply for resuscitators and in-water decompression as well as for shipboard mono-place and multi-place chambers.

Section Three:

Looking Ahead

New Technologies
Prepared by Lynne Carter Hanson

Background/Summary

There are many technologies coming into use by the scientific diving community that are beyond those traditionally used by scientific divers. Many of these *new* technologies are not new at all but have a long history of industrial and *other* diver group usage (e.g., NOAA use of NITROX). When adopting additional technologies into the repertoire of scientific diving, a variety of mechanisms have been used which range from personal discussions to the convening of a workshop (e.g., American Academy of Underwater Sciences' Workshop on Diving Computers) and development of standards for and by the community. The four perspectives concerned with additional technologies and mechanisms to deal with them are:

The general term 'diving' is used to indicate scuba or surface supplied diving, but not excursions beneath the surface in either an OMADS or a multi-place submersible.

- The ship operator with overall responsibility for *over-the-side* operations;
- The scientist with his or her need and desire to accomplish *good* science;
- The scientist's home institution with its concerns for safety, liability, and reputation; and
- The funding agency which is responsive to community demands and at the same time responsible for (among others): safety, finances, and precedent setting issues.

Control of all hyperbaric exposure by employees of research institutions has traditionally rested with Diving Control Boards. These groups are also responsible for the development of new protocols and standards for new equipment and situations (e.g., diving computers, HELIOX, NITROX, cold water diving, diving tables, multiple tether diving, etc). Recently two issues of broad concern to the scientific diving community (diving computers and biomechanics of ascents) have been addressed by AAUS workshops.

The specifics of a research dive are not traditionally the concern of the ship operators as long as they feel confident that the planning has been sufficient to result in a safe and successful operation. The establishment of campus diving administrations in the form of Diving Control Boards as documented by AAUS standards has been well accepted and successful. The development of rules, standards, and protocols for new personal equipment will likely follow the traditional model of: first, an increase in interest by the research diving community for use of the technology; then the development of a community standard.

When it comes to a broad range of issues related to diving, there are other groups and societies that are, and should continue to be, involved. For example, the issue of the frequency and content of a diving medical exam is more clearly the purview of a group such as the UHMS than AAUS, MTS, or UNOLS.

The issues of availability, as well as protocols and standards development, are not as clearly delineated when it comes to the use of One-Man Atmospheric Diving Systems (OMADS) and Remotely Operated Vehicles (ROVs). Part of this results from these new technologies not yet attaining the level of use that, for example, scientific diving has reached. There was a time in the history of scientific scuba diving when it was unregulated and a pioneer activity. As it became more regularly utilized, recognition of the need for standards and guidelines brought about their development.

If a higher level of use and commonality of new technologies is foreseen, then protocols and standards need to be developed. Again, using the research diving analogy, it makes sense that the user community be self-regulating and codify generally accepted practice before often unworkable and occasionally dangerous rules and regulations are imposed from the outside. To deal with the policy and technical issues of availability, technical complexity, and training and safety of all research submersibles, manned and unmanned, the establishment of a UNOLS committee, the In Situ Science Committee (ISSC), is suggested. The ISSC should, like the AAUS Standards Committee, be accepted by the community and the agencies.

The issues related to guideline development for the use of underwater vehicles can be divided into a number of sometimes overlapping areas:

- **availability** in terms of: scientific need, user mechanisms, resources, and vehicles;
- the **technical complexity** of operating and maintaining the vehicle (including over-the-side considerations); and
- the training and safety of using a **scientist as pilot**.

Availability:

- **Scientific need:** There are a number of reports (e.g., The Jennings Report[14] by NOAA, the Low-Cost ROV and Submersible Workshop Report[15] by the University of Rhode Island's Center for Ocean Management Studies, and the UNOLS Submersible Science Study[16]) that point out that portions of the science community have a requirement for increased availability of undersea vehicles. According to the UNOLS *Submersible Science Study* (S^3):

  > The principal problem confronting the (oceanographic) research community is the lack of access to submersible systems. These will be primary tools of the next generation of oceanographers; yet while the technology continues to evolve, the development of research methodologies for their utilization is lagging far behind.

  This comment reflects the growing recognition of the importance of these new tools to the advancement of oceanography.

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[14] 'New Directions for NOAA's Undersea Research Program.' Jennings, F. D.: 1986, Texas A & M University, College Station TX.

[15] 'The Marine Research Community and Low Cost ROVs and Submersibles: Needs and Prospects,' Hanson L. C.: 1986, Center for Ocean Management Studies, University of Rhode Island, Kingston, RI.

[16] 'Submersible Science Study,' Robison, B. (Chairman), 1990: University National Oceanographic Laboratory System, University of Washington, Seattle, WA.

- **User mechanisms, resources and vehicles:** The use of OMADS with federal funding is an important issue that requires some attention. There is no consistent policy across the federal government for the use of OMADS. NOAA does not allow even the *consideration* of OMADS as a tool for use with their funding while NSF has funded OMADS demonstration dives as well as successful field programs and NPS/DOI (National Park Service, Department of the Interior) has encouraged OMADS use as the most appropriate tool for specific scientific projects. There appears to be a connection between the lack of consistent federal policies, the lack of federally recognized operational standards and the federal reluctance to make these new technologies readily available to the science community. The reports cited above state, unequivocally, that the demand for the use of manned and unmanned submersible systems will continue to grow. A standardized mechanism must be developed to assure safety and efficiency as well as provide federal consistency in available fiscal resources for the use of manned and unmanned submersibles for scientific purposes. The mechanism could utilize either local (modeled on that of a Diving Control Board) or national (like the AAUS Standards Committee) models to accomplish this goal depending on vehicle complexity and cost.

  Another aspect of this dilemma is that of cost. Who is going to pay? This is a valid concern. There are those in the community who feel that the use of any submersible should be like the use of ALVIN or regular shiptime. That is, requests for submersible support should be handled through regular federal facilities funding channels. There are others who feel that the science budget should directly fund the use of these new technologies. There is a mechanism for moving new marine technologies from the drawing board through the proving stage. However, the mechanism does not follow through by bringing those proven new technologies on-line. The agencies need to complete the loop that they have established by developing a method to fund the use of proven new technologies. This funding mechanism must be responsive to the demands of the scientific user community.

Technical Complexity

On the **technical** side, the community has recently relied on the turn-key, leased vehicle approach which includes the owner/operator's personnel, protocols, and practices. The variety and type of vehicles that are available continues to grow. It would be useful to the scientific community to have a mechanism to evaluate and utilize new capabilities as they come on line. The lease method has worked well and brings with it the technical component important to successful operations. For ROVs, the community has either utilized operator-developed protocols, developed their own documented procedures or relied on the operating procedures developed by MTS[17]. Even with a lease approach, there have been irregularities in the availability of vehicles for use by the scientific community, with much of the irregularity originating from the availability issues discussed above.

[17] 'Operating Guidelines for Remotely Operated Vehicles,' Wernli, R.L. (Chairman): 1984, Marine Technology Society, San Diego Section, San Diego, CA.

Training Scientists as Pilots

The third issue of the **scientist as pilot** lends itself to community action through the development of standards of training, safety, and practice much like the self-developed and self-imposed diver training standards of the AAUS. Although AAUS is not the best organization for the development of these protocols, its mechanisms are a good model to follow. The actual development of standards could be left to interested university boards (in cooperation with vehicle operators) and submitted to the oversight group or be prepared by the ISSC itself.

Concluding Comments

The workshop participants expect underwater vehicle use (especially OMADS) to become widespread. This will require the codification of a set of national minimum operating standards. As a result, it is crucial that the ISSC be made up of people with expertise and interest in the use of manned and unmanned underwater technologies. The ISSC's authority and usefulness depends upon the level of expertise of its members. The user community will closely watch the appointment process and will take the ISSC and its recommendations seriously only if they feel it both representative and knowledgeable.

The development of guidelines and related items by a community-accepted organization would serve to: reduce the anxiety of the ship operators related to the on-board and over-the-side use of all underwater vehicles; address concerns of the funding agencies related to safety procedures and liability; and be a first step in the development of a mechanism to promote up-dates and better communication on the availability, use, and protocols related to new technologies. There are many concerns that could be addressed by the ISSC that would be beneficial. They include but are not limited to: insurance, safety, pilot training, shipboard handling, institutional operations, ship-of-opportunity transfers, leasing mechanisms, and regular inter-group communications and up-dates (e.g., meetings between UNOLS, RVOC, new committees, agencies, scientists, AAUS, etc.)

Considering the above discussion, the following **recommendations** resulted:

- AAUS should continue to be **involved in non-submersible scientific diver issues**;
- **Other societies** should be encouraged to remain involved in issues of their **expertise;**
- Representatives of the various groups should **meet together** periodically to facilitate communication; and
- **UNOLS should establish a standing committee called the In Situ Science Committee (ISSC)** to:
    - assess the current development, availability, and appropriate applications of 'new' technologies for in situ science;
    - advise NSF, ONR, NOAA, and other federal agencies on in situ technologies, their evolution and application;
    - foster the incorporation of these new technologies into federally funded marine research;
    - establish consistent operational standards for new technology equipment for use by the science community;
    - establish guidelines and provide oversight for the contracting, safety, and insurance for leased, in situ, new-technology equipment (foreign and domestic);
    - coordinate and promote the efficient joint scheduling of submersibles or other in situ equipment on an inter-agency basis; and
    - promote the establishment of a shared-use equipment pool and tool inventory.

Emphasis for the ISSC would be on current submersible technologies as well as new technology issues that involve substantial departure from current practice in oceanographic research with respect to operations, safety procedures, or personnel training. Examples would include, but are not limited to: submersibles, OMADS, ROVs, AUVs, and combinations. It would *not* involve itself in scientific proposal review but rather could offer technical and operational review in the form of assessments and adequacy of the tools and the procedures proposed.

Issues for consideration by this committee could arise from within the committee or from sources outside it, including:

- UNOLS;
- federal funding agencies;
- other government bodies;
- the academic oceanographic science community;
- marine technology industry;
- international marine scientists and institutions; and
- other interested and appropriate parties.

Issues which this committee deems inappropriate for its consideration could be referred to other expert bodies (e.g., UHMS for medical concerns, AAUS for scuba diving issues, and MTS for engineering questions, etc.).

Committee Composition

This committee should broadly represent the marine community including participants from the following groups:

- research vessel operators;
- commercial marine technology community;
- academic oceanographic community;
- Diving Safety Officers from UNOLS institutions; and
- as observers: representatives of the funding and regulatory agencies.

Committee Structure

In the UNOLS structure the ISSC would occupy a position comparable to the RVOC and the Fleet Improvement Committee (FIC). Since the charge to the ISSC encompasses all in situ technologies, it would seem logical that the ARC would eventually become a permanent subcommittee within it.

The Fleet Improvement Committee is a committee of UNOLS. It works to assure the continuing excellence of the UNOLS fleet, to improve the capability and effectiveness of individual ships and to assure that the number, mix and overall capabilities of ships in the UNOLS fleet match the science requirements of academic oceanography in the U.S. It is composed of a Chair and seven members who are experienced in ship operations and are from institutions which are either operators or users of UNOLS research vessels.

There are two mechanisms that could be employed in the structuring of this committee (apart from the ARC component). One is to appoint a large ISSC committee whose members could be divided into functional groups to address identified problems. The second mechanism would create a smaller standing ISSC which could convene ad hoc panels of outside experts to deal with specific issues. ■

Future Needs and Projects

Prepared by Mike Lang

One of the primary reasons for this workshop was to increase communication between the various parties involved in a research diving cruise. Vessel operators rarely know of the existence of research diving safety programs on any campus but their own and, due to a lack of first hand experience, lack confidence in any research diving safety programs other than the one on their campus. This general feeling of discomfort is exacerbated by the difficulties (and occasionally confusion) surrounding the qualification of research divers whose home institutions do not have a research diving safety program.

To help the implementation of workshop recommendations, insure the orderly evolution of future standards and guidelines, meet future needs of the research diving community and academic fleet, and obviate the need to conduct a workshop similar to this one in the near future, formal links between the major organizations concerned with shipboard research diving need to be forged.

The lack of a formal structure linking UNOLS/RVOC, AAUS and NOAA concerns for research diving safety has been an impediment to routine progress on issues of research diving safety within the academic fleet. This lack of inter-relationship and coordination between UNOLS/RVOC and AAUS is perplexing since a substantial congruity of membership exists between UNOLS/RVOC and AAUS, and there is a high level of AAUS activity within the UNOLS/RVOC community and a significant commonality of interest.

This commonality of interest is evidenced by extensive informal links such as AAUS members contributing sections to and reviewing sections of the *UNOLS Shipboard Safety Standards* and the *RVOC Safety Training Manual*; AAUS issuing and periodically revising the diving standards under which research divers at UNOLS institutions are trained and certified and which are used for the administration of research diving programs at UNOLS institutions; AAUS providing the only framework for inter-institutional reciprocity and acceptance of research diver certification within the UNOLS community.

AAUS has been the single national body representing the United States' research diving community for more than a decade. AAUS has represented research diving community interests before Presidential Commissions and Federal agencies; provided the only significant national forum for the exchange of information dedicated to underwater science accomplished by research divers; convened panels of experts to study and supply guidance on the use of new diving technologies; provided an interface with the international research diving community; compiled statistics concerning research diving activities, accidents and exposures; and provided a forum for the Diving Safety Officers and institutional representatives to meet and discuss items of common interest.

UNOLS/RVOC and AAUS will continue to work on behalf of their memberships, within the scope of their missions and available resources. The development of a structure integrating research diving safety concerns will add to research diver safety and expand the capabilities of the research diving community by establishing consistency and reducing duplication of effort. Examples of benefits include:

- Making AAUS more available (and directly responsive) to UNOLS/RVOC for consultation and advice on questions concerning or affecting research diving.
- Having AAUS provide, at UNOLS request, an external review function for diving cruises;
- Providing a structure for peer review of science proposals involving research diving which would include the best available review of diving operational safety and feasibility considerations.

Recommendations

A) Formal links between UNOLS/RVOC should include (but not be limited to):

1) Requiring Organizational Membership in AAUS of UNOLS institutions that:

a) Operate vessels carrying research diving cruises, and
b) Who have research divers participating in such cruises;

2) Reciprocal representation at each others meetings;

3) Identified sections in each others' newsletters; and

4) Occasional joint meetings.

B) Supplying technical links (as part implementation of the S^3 Report), through UNOLS setting up a Diving Safety Officers sub-committee under the proposed In Situ Science Sub-Committee (ISSC); and the AAUS Board of Directors setting up a UNOLS Diving Officer Committee within the AAUS.

C) Research diver safety and efficiency would be enhanced if in addition to creating UNOLS/RVOC links with AAUS, similar links, at the operational research diving level, were created with NOAA. Academic diving and NOAA diving programs should aggressively pursue a reciprocity agreement covering research diver certification. This link could provide a model for future cooperation on the safety, efficiency, and consistent utilization of new technologies. ◼

Appendices

Appendix A: Schedule of The URI/GSO Workshop on Scientific Shipboard Diving Safety

SUNDAY, 18 FEBRUARY 1990				
0700	**Breakfast - 1 hr.**			
0800	Welcome and Introduction		Dolly Dieter for NSF	
			Leon Greenbaum for UHMS	
			Jim Griffin - Workshop Details	
0900	Marine Operator and Diving Issues: 1) Organization Description. 2) Perspectives on the problem. 3) Review of Documents.		Jim Williams - UNOLS	
			Jack Bash - RVOC	
			Chuck Mitchell - AAUS	
1030	**Break - 1/2 hr**			
1100	Perspectives on the Problem: Science Issues		Larry Madin Alice Alldredge Bob Stenneck Jon Witman	
1220	**Lunch - 1 hr**			
1320	Blue Water Diving: Description and Terminology		Bob Sand	
1345	The Matrix Tool: A General Explanation		Jim Griffin & Bob Sand	
1415	Introduction to Case Studies		Jim Griffin	
1430	Task Group Meetings. Group chairperson is underlined in **bold type**.	Group 1: **Bob Stenneck**, Phil Sharkey, Tim Askew, Bill Fife, Lynne Hanson, Dolly Dieter, David Casiles.	Group 2: **Jim Williams**, Alice Alldredge, Jim Griffin, Jack Nichols, Mike Lang, Leon Greenbaum.	Group 3: **Jim Stewart**, Jon Witman, Jack Bash, Chuck Mitchell, Tom Hall, Bob Sand, Larry Madin.
1730	**Break - 1/2 hr, Dinner - 1 1/2 hr**			
1930	Task Group Reports		Task Group Chairs from 1430	
2100	Daily adjournment review.		Jim Griffin	

MONDAY, 19 FEBRUARY 1990		
0700	**Breakfast - 1 hr**	
0800	Introduction to Topic Sessions	Jim Griffin
0830	Topic Session #1: Multi-Institutional Diving Cruises.	Larry Madin, Jim Stewart, Bob Sand, Jack Bash, Chuck Mitchell.
0930	Topic Session #2: Additional Personnel for Diving Cruises.	Jim Williams, Bob Stenneck, Jim Stewart, Jack Bash.
1030	**Break - 15 min**	
1045	Topic Session #3: Responsibility Statements.	Jack Bash, Alice Alldredge, Jim Stewart, Dolly Dieter, Jim Williams, David Casiles.
1145	**Lunch - 1 hr 15 min**	
1300	Topic Session #4: Diver Training Standards.	Chuck Mitchell, Jon Witman, Phil Sharkey, Tim Askew.
1400	Topic Session #5: Small Boats and Small Boat Operators.	Tim Askew, Jack Nichols, Mike Lang, Alice Alldredge, David Casiles.
1500	**Break - 15 min**	
1515	Topic Session #6: Emergency Planning and Accident Management.	Tom Hall, Bob Sand, Jim Williams, Jack Nichols, Leon Greenbaum, Bob Stenneck.
1615	Topic Session #7: Recompression Chambers.	Bill Fife, Alice Alldredge, Tom Hall, Phil Sharkey, Tim Askew.
1730	**Break - 1/2 hr, Dinner - 1 1/2 hr**	
1930	Topic Session #8: New Technologies Issues	Lynne Hanson, Larry Madin, Jack Nichols, Jim Williams, Mike Lang, Bill Fife.
2100	Daily adjournment review.	Jim Griffin

TUESDAY MORNING, 20 FEBRUARY 1990		
0700	**Breakfast - 1 hr**	
0800	**Checkout of hotel**	
0830	Checklist Development	**Jack Bash**, Tim Askew, David Casiles, Jon Witman, Dolly Dieter.
0900	Continuity and New Tasks	**Mike Lang**, Alice Alldredge, Dolly Dieter, Lynne Hanson, Jim Williams.
1030	**Break - 15 min**	
1045	Review of progress on Tasks, Recommendations, Action Items, et al and Schedules of Downstream work.	Jim Griffin
1200	**Adjourn URI/GSO Workshop**	

Appendix B: List of Attendees

Alice Alldredge	Professor Biological Sciences University of California Santa Barbara, CA 93106
Timothy Askew	Operations Director Harbor Branch Oceanographic Institution 5600 Old Dixie Highway Ft. Pierce, FL 34946
Jack Bash	Marine Superintendent Graduate School of Oceanography University of Rhode Island Narragansett, RI 02882
David Casiles	Research Vessel Captain (ret.) Falmouth, MA 02543
E.R. Dolly Dieter	Program Manager Ship Operations Division Of Ocean Sciences, Room 609 National Science Foundation 1800 G. St NW Washington, D.C. 20560
William Fife	Director Hyperbaric Lab Texas A & M University College Station, TX 77843
Leon Greenbaum, Jr.	Executive Secretary Undersea & Hyperbaric Medical Society 9650 Rockville Pike Bethesda, MD 20814
James J. Griffin	Director of Facilities Graduate School of Oceanography University of Rhode Island Narragansett, RI 02882
Thomas Hall	Special Operations Director Medical Advisory System Box 193 Pennsylvania Ave Ext Owings, MD 20736
Lynne Carter Hanson	Executive Director Center for Ocean Management Studies University of Rhode Island Kingston, RI 02881
John Harper	Special Operations Director Medical Advisory System Box 193 Pennsylvania Ave Ext Owings, MD 20736

Michael Lang	President-Elect AAUS Scientific Diving Officer/OASR A & I Building, Room 2201 Smithsonian Institution Washington D.C. 20560
Laurence Madin	Senior Scientist Woods Hole Oceanographic Institute Woods Hole, MA 02543
Charles Mitchell	President- AAUS Marine Biological Consultants Inc. 947 Newhall Street Costa Mesa, CA 92627
Jack Nichols	Diving Safety Officer RSMAS Dive Office University of Miami 4600 Rickenbacker Causeway Miami, FL 33149
Robert Sand	Chairman, Diving Control Board Graduate School of Oceanography University of Rhode Island Narragansett, RI 02882
Phillip Sharkey	Diving Safety Officer Graduate School of Oceanography University of Rhode Island Narragansett, RI 02882
Robert Steneck	Professor Darling Marine Center University of Maine Walpole, ME 04573
James Stewart	Diving Safety Officer Mail Code A-010 Scripps Institution of Oceanography La Jolla, CA 92093-0210
Jon Witman	Professor Northeastern University Marine Sciences Center East Point Nahant, MA 01908
James Williams	Marine Superintendent Scripps Institution of Oceanography Nimitz Marine Facility PO Box 6730 San Diego, CA 92106

Appendix C: Notes on the Matrix
Prepared by Phil Sharkey

Background

A primary goal of the workshop was close examination of the responsibility and authority of UNOLS diving cruise participants. This needed to be done so that workshop recommendations established congruency between the items and events that each cruise participant had authority over and those that the participant was responsible for. This is an exceedingly complex task, made more formidable by the conflict between the tradition that a ship's Master is answerable for all that happens, and the reality that research divers, once they are in the water, are not in contact with the ship and operate independent of any outside control.

The matrix was designed as a tool that would supply a structure for evaluating the assignment of authority and responsibility for each component of a cruise to all personnel involved in the cruise. It was designed to provide:

A) a starting point for the workshop that would focus on the critical issues;
B) a level of objectivity to the questions raised, particularly those involving authority and control;
C) an objective means of dissecting the administrative layers involved with shipboard diving;
D) a framework for discussing the complex, interrelated topics; and
E) a check for conditions where a solution would exacerbate or cloud another issue(s).

The actual development of the workshop version of the matrix included:

A) A list of all the cruise participants (individuals and organizations) who might be involved in a diving cruise was prepared. This list was arranged into functional units, such as ship's personnel, science party and diving administration.
B) Similarly, the events (real as well as conceivable) of a diving cruise were compiled and arranged into chronological order.
C) The cruise participants were placed on the ordinate of a chart and the events on the abscissa.
D) The matrix was circulated so that overlooked cruise participants or events could be added.
E) The matrix was applied to case studies from diving cruises as a check for completeness.

At that point the matrix was sent out to all workshop members. They were asked to inspect it and to apply it to any diving cruise case studies they had.

Early in the workshop, a session was held to present a short example of the application of the matrix to a case study. The workshop participants divided into three task groups to examine the matrix in detail. Each task group was carefully designed to include members from each constituency (operator, science, diving administration). One task group was chaired by a representative of each constituency. The task groups were asked to perform two assignments:

A) Review each cruise event, determine which listed individuals and organizations were involved in that event (adding any overlooked participants) and rank the participants' involvement with respect to their own subjective appreciation of the participants' level of combined authority and responsibility.
B) Conduct a detailed examination and review of several case studies and determine that their rankings were appropriate.

The workshop members' initial impression was that the matrix might be an unreasonable amount of work; however, all the task groups completed their review and at least one case study in the allotted three-hour time period. There was agreement that the matrix met the three goals listed above.

It was more useful than a simple checklist. The matrix deals in two dimensions, while a checklist is uni-dimensional. Since the major workshop task deals with interfacing groups of people, the matrix's contribution to identifying the points (and effects) of interaction was vital.

Three assumptions were identified and concern over them was expressed:

A) Different institutions conduct their business in different ways using different structures, titles, etc. This complicates deliberations and could lead to misconstruing findings and recommendations.
B) The matrix design was based on cruises funded through NSF which are conducted aboard UNOLS vessels. This could bias the matrix analysis and results and lessen the applicability of findings and recommendations to other types of diving cruises (e.g., platforms of opportunity, NOAA, institutionally funded cruises, EPA).
C) The matrix starts with proposal writing and is oriented to events and actions. It does not address the skills, knowledge and experience (or lack thereof) that the various cruise participants bring to the process. As a result, findings and recommendations concerning the training of cruise participants will be missed by analysis of the matrix.

Specific recommendations for changes in the matrix included:

A) Addition of a line for specialized training in the diving techniques to be employed during a cruise such as a dive that is conducted at the start of the cruise.
B) Addition of a 'brief dive team' item which includes 'assign dive team roles.'
C) Addition of an 'identify potential hazards on site' line.
D) Addition of a line for keeping watch on the dive team from the ship.
E) Addition of a line for medical oxygen.
F) Combination of the 'small boat equipment' and the 'small boat emergency equipment' lines.
G) Elimination of lines concerning special personnel which could be subsumed under other categories.
H) Elimination of the redundancy of separate lines for specifying, obtaining, inspecting and approving.

The workshop participants thought that, in a fully developed form, the matrix would serve as an effective guide for assuring compliance with regulations and standards. It would also be of help in analyzing accidents/incidents with an eye to clearer definition of responsibilities so that problems could be avoided in the future. The participants recommended that further development of the matrix be organized to illustrate that a cruise has three phases where different primary groups interact:

A) At the start of a program the Principal Investigator develops a proposal and communicates frequently with the Marine Office and home campus diving administration.
B) The next phase begins when the proposal has been funded and preparation for the cruise begins. This phase involves the campus diving administration of the home and operating institutions and the science party interacting in a variety of ways.
C) During the operational phase, the interactions are primarily between the people on board the ship, the Master, crew, science party, On-Board Diving Supervisor, etc.

Cases of equal ranking of responsibility were identified by all the task groups. This did not mean that everyone identified had to perform the task, or check on the item, but that all those identified had veto power over the outcome. For example, approving the emergency plan was seen to involve the Marine Office, the ship's Master, the home and operator Diving Safety Officers and campus diving administrations and the On-Board Diving Supervisor. All these participants did not have to be involved in the preparation of the plan, but all of them had the right to send it back to the drawing board.

Fifteen different matrix cells where the Master was involved were identified by one task group. This result surprised the task group. It was seen as a clear-cut step in the right direction and was cited as a valuable contribution of the matrix that should be brought out if there is future development of the matrix.

There exists, by design, a high correlation between the matrix, the *UNOLS Shipboard Safety Standards*, the AAUS standards and the diving safety manuals of most institutions. Future work on the matrix design will recognize these existing systems of standard practices. As much as possible the matrix will also reflect the normal practices that currently assure cruise participant communication (e.g., the Marine Office contacts the Master, the Master contacts the bridge or engine room and vice versa).

It was suggested that a condensed form of the matrix be used as a checklist. If all the items listed on the matrix were part of a checklist, that would be the basic backbone of what should take place on a cruise. Such a checklist should start even before the proposal is submitted, since it would result in the early identification of requirements for diving-safety-related equipment and personnel. A Principal Investigator would thus cover all the safety bases and there would be no surprises after a budget has been approved.

<u>Summary:</u>

In a fully developed form, the matrix would serve as an effective guide for assuring compliance with regulations and standards. It would also be of help in analyzing accidents/incidents with an eye to clearer definition of responsibilities so that problems could be avoided in the future. The workshop recommends that efforts be made to develop the matrix further. ◼

Item		Marine Office	Ship Personnel						Diving Safety Administration				Science Party				MAS DAN
			Captain	Watch			Boat Operator	Other Crew	Home DCB	Operator DCB	Operator DSO	Home DSO	Chief Scientist	Diving Supervisor	Safety Diver	Research Diver	
				Bridge	Engine	Deck											
Proposal	Wrtg																
	In-hse review																
	Fundg																
Ship Scheduling	Shipquest																
	Shipschedule																
Diver Qualification	Hm Institution																
	Opting Institution																
	Apprvl of divers																
Identification of lead DCB	Prep																
	Des																
Approve Tables																	
Diver Credentials	Sbmt																
	Rvw																
Cruise Plan	Prep																
	Apprv																
Emergency Plan	Prep																
	Apprv																
Dive Plan	Prep																
	Apprv																
Identify Potential Hazards	Environmental																
	Biological																
Require Special Personnel	Dive Supervisor																
	Sci Diver(s)																
	BoOperator(s)																
	ShLiaison																

Item		Marine Office	Ship Personnel						Diving Safety Administration				Science Party				IMAS DAN
			Captain	Watch			Boat Operator	Other Crew	Home DCB	Operator DCB	Operator DSO	Home DSO	Chief Scientist	Diving Supervisor	Safety Diver	Research Diver	
				Bridge	Engine	Deck											
Select Special Personnel	Dng Supervisor																
	Sty Diver(s)																
	Bt Operator(s)																
	St Liaison																
Approve Special Personnel	Dng Supervisor																
	Sty Diver(s)																
	Bt Operator(s)																
	St Liaison																
Personal equipment	Sfty																
	Oln																
	Inct																
	Arove																
General diving equipment	Sfty																
	Oln																
	Inct																
	Arove																
Special equipment	Sfty																
	Oln																
	Inct																
	Arove																
Small boat equipment	Sfty																
	Oln																
	Inct																
	Arove																
Small boat procedures	Sfty																
	Arove																

Item		Marine Office	Ship Personnel						Diving Safety Administration				Science Party				MAS DAN
			Captain	Watch			Boat Operator	Other Crew	Home DCB	Operator DCB	Operator DSO	Home DSO	Chief Scientist	Diving Supervisor	Safety Diver	Research Diver	
				Bridge	Engine	Deck											
Small Boat Emergency Procedures	Specify																
	Obtain																
	Inspect																
	Approve																
Brief Master on cruise																	
Conduct diving emergency drills																	
Schedule dive																	
Define dive abort criteria																	
Cancel dive																	
Assign dive-team roles																	
Brief master on specific dive																	
Inform engine room of dive																	
Launch small boat																	
Operate small boat																	
Recall divers																	
Give first responder care																	
Give EMT level care																	
Interface with MAS in emergency																	
Interface with DAN in emergency																	
Keep dive logs																	
Calculate/check RNTs																	
Fill tanks																	
Repair diving equipment at sea																	
Upgrade diver status at sea																	
Restrict/suspend diver																	
Cancel diving operations																	
Cancel cruise																	

Appendix D: American Academy of Underwater Sciences Bibliography

Key	Proceedings title	Editor
1	Diving for Science...81	Abstracts
2	Diving for Science...82	Abstracts
3	Diving for Science...83	Abstracts
4	Diving for Science...84	Abstracts
5	AAUS/CMAS Diving for Science...85 Proceedings	C.T. Mitchell
5a	AAUS/CMAS Diving for Science...85 Proceedings Addendum	C.T. Mitchell
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7 Dry suit diver training course - C.M. Flahan
7 Alternate air sources: Problems and procedures - D. Graver
7 Coldwater SCUBA diving search and recovery operations - C. Lewis
7a Cold water diving logistics - J.R. Stewart
7a Operational strategies for Arctic research diving - B.E. Townsend
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2 A comparison of reef fish community assessments using the transect method and the random count method - Mark Helvey
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2 An underwater visibility comparison of Lake Tahoe and Crater Lake - Donald G. Morris and Carol R. Morris
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2 Saturation diving as a tool for marine scientists - Steven Neudecker
2 Saturation research diving: A new tool for marine research - Dale Anderson
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3 Research diving on the strategic petroleum reserve projects, Northern Gulf of Mexico - Donald E. Harper and Larry D. McKinney
3 The shark observation submersible: A diver vehicle for the study of shark behavior - Donald R. Nelson
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Appendix E: Shipboard Diving Procedures

by James R. Stewart

This article is included to provide historical perspective and to illustrate the long standing, effective, self-regulation of the U.S. research diving community. While some of the details in the sections on *Diving Equipment* and *Diving Procedures* are dated, the *Cruise Planning*, *Pre-Dive Procedures* and *Emergency Procedures* sections are quite current. This article was originally published as *Shipboard Diving Procedures* in Part III of *The Scripps Institution of Oceanography Marine Technicians Handbook*.

Shipboard diving is quite different from small boat diving or shore-based operations and is, therefore, worthy of comments to aid the inexperienced. At all times it must be understood that the ship's Master has final decisions in any operation concerning his vessel.

I. Cruise Planning

Any cruise involving diving operations should be planned in advance to allow loading positioning and securing of critical equipment, i.e., compressors, volume bank, diving tanks, etc. The compressor should be positioned with intake toward the bow of the ship (the ship will swing into the wind while at anchor), away from exhausts from main, auxiliary, or any other engines, and free from fume contamination from paint lockers, or gasoline and other solvent handling. Cool running of the compressor requires good ventilation, and should be perhaps used only at night in hot climates. When filling air cylinders, salt water from the ship's sea-water system may be turned on the tanks as a coolant. Oil-lubricated compressors should have some type of oil/water separator built into the system, and it is highly desirable to have a filtration column which eliminates CO, CO_2, hydrocarbons, oil, water, and any other contaminants in accordance with breathing air specifications. Also desirable is a small colorimetric test kit to determine air quality*. Permanent compressor installations should be under jurisdiction of the ship's engineering staff for maintenance purposes, and a log kept for review of appropriate oil and filter changes.

II. Diving Equipment

Diving equipment should be stored in an area where it can be dried. This designated 'Diving Locker' should be well ventilated and lockable, with the key under the supervision of the ship's Master. Minimum equipment includes two complete sets of the following:

(a) regulators
(b) air cylinders and back packs
(c) depth gauges
(d) masks
(e) fins (with adjustable straps)
(f) snorkels
(g) knives
(h) weight belts and at least a total of 40 pounds of weights
(i) inflatable life vests

A tank pressure gauge, an assortment of 'goody' bags, and spares of the gear listed above are additional basic requirements. Personal wet suits and watches are provided by each diving individual.

Surface signals (flares, whistles) and some sort of anti-shark devices are required in open sea diving. They must be included and used.

* These may be obtained from Mine Safety Appliance Corporation, Draeger Corporation and Kitagowa Corporation.

III. Pre-Diving Procedures

The ship's Master ultimately has authority over diving operations from his vessel. He should insure that those proposing to dive have proper authorization, either University Certification cards or 'letters of approval.' All diving is to be conducted in accordance with the University Guide for Diving Safety. The Senior Diver, determined during the Cruise Planning phase, will act as liaison with the ship's crew, and act as supervisor of diving operations. His responsibilities include insuring that proper equipment is available in good condition, logging divers in and out of the water, considering emergency and standby equipment and procedures, and maintaining proper records.

Liaison, besides general communication, between diving and other personnel, specifically involves notifying the Master, the ship's engineers, and the cook (garbage overboard is an attractant), of preparations for diving operations, and transmitting a safe go-ahead response to the divers before anyone enters the water.

IV. Diving Procedures

Small boats or rafts are generally necessary for water entry, for use as platforms, or for transportation. A third person, at least, should remain in the boat. Currents often are sufficiently fast to prohibit a diver from swimming up-stream to return to the boat. When a dive is made under the hull or when current direction is known, entry to the water should be made over the bow and the anchor line used for descent; divers obviously should work upstream away from the ship, remembering currents tend to be fastest toward the surface.

Under-way diving necessitates two boat tenders, one to bubble-watch and assist the divers, and one to run the boat. In advance of the exercise the best plan should be determined to permit the divers to stay together while the boat maneuvers to them. Inflatable life vests and anti-shark devices (knives) must be worn/carried in open sea diving work.

Fishing and diving operations must never be carried on simultaneously. If diving under the ship is imperative due to fouling of the propeller, heavy tools ought to be lowered to the diver in a 'goody' bag. One diver, of a pair, should work while a second acts as lookout. (Before any water entry, divers should check to see if sharks are following the ship.)

V. Emergency Procedures

Routines and equipment should be outlined before embarking. The ship's physician should have knowledge of diving accidents and requisite first aid procedures. References such as U.S. Navy Diving Manual should be included in his library. Recompression chambers and the means of getting a diver to one ought to be charted for the entire itinerary. ◾

Appendix F: AAUS Guidelines for the use of Dive Computers

1. Only those makes and models of dive computers specifically approved by the Diving Control Board may be used.

2. Any diver desiring the approval to use a dive computer as a means of determining decompression status must apply to the Diving Control Board, complete an appropriate practical training session and pass a written examination.

3. Each diver relying on a dive computer to plan dives and indicate or determine decompression status must have his own unit.

4. On any given dive, both divers in the buddy pair must follow the most conservative dive computer.

5. If the dive computer fails at any time during the dive, the dive must be terminated and appropriate surfacing procedures should be initiated immediately.

6. A diver should not dive for 18 hours before activating a dive computer to use it to control his diving.

7. Once the dive computer is in use, it must not be switched off until it indicates complete out-gassing has occurred or 18 hours have elapsed, whichever comes first.

8. When using a dive computer, non-emergency ascents are to be at the rate specified for the make and model of dive computer being used.

9. Ascent rates shall not exceed 40 fsw/min in the last 60 fsw.

10. Whenever practical, divers using a dive computer should make a Stop between 10 and 30 feet for five minutes, especially for dives below 60 fsw.

11. Only one dive on the dive computer in which the NDL of the tables or dive computer has been exceeded may be made in any 18 hour period.

12. Repetitive and multi-level diving procedures should start the dive, or series of dives, at the maximum planned depth, followed by subsequent dives of shallower exposures.

13. Multiple deep dives require special consideration. ■

Appendix G: AAUS Safe Ascent Recommendations

It has long been the position of the American Academy of Underwater Sciences that the ultimate responsibility for safety rests with the individual diver.

The time has come to encourage divers to slow their ascents.

1. Buoyancy compensation is a significant problem in the control of ascents.
2. Training in, and understanding of, proper ascent techniques is fundamental to safe diving practice.
3. Before certification, the diver is to demonstrate proper buoyancy, weighing and a controlled ascent, including a 'hovering' stop.
4. Divers shall periodically review proper ascent techniques to maintain proficiency.
5. Ascent rates shall not exceed 60 feet of sea water per minute.
6. A stop of the 10 to 30 feet of sea water zone for three-to-five minutes is recommended on every dive.
7. When using a dive computer or tables, non-emergency ascents are to be at the rate specified for the system being used.
8. Each diver shall have instruments to monitor ascent rates.
9. Divers using dry suits shall have training in their use.
10. Dry suits shall have hands-free exhaust valves.
11. BC's shall have a reliable rapid exhaust valve which can be operated in a horizontal swimming position.
12. A buoyancy compensator is required with dry suit use for ascent control and emergency flotation.
13. Breathing 100 percent oxygen above water is preferred to in water air procedures for omitted decompression.